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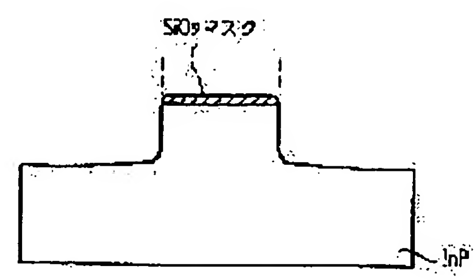
(54) ETCHING OF COMPOUND SEMICONDUCTOR, SEMICONDUCTOR LASER ELEMENT, AND MANUFACTURE THEREOF

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a method for dry-etching a compound semiconductor to form a vertical, smooth etched surface thereof.

SOLUTION: In the etching method, a dry etching apparatus having a plasma generation source for generating plasma having a density of about 1010cm-3 or more is used to subject a family III-V compound semiconductor or a family II-VI compound semiconductor to a dry etching process with use of a mixture of a gas containing halogen elements and a nitrogen gas. At this time, it is set to approximately satisfy a relationship of (flow rate of a gas containing halogen elements)/(flow rate of nitrogen gas) ≥ 1, and a pressure in the etching reaction is set at about 1mTorr or more.



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CLAIMS

[Claim(s)]
[Claim 1] It is the etching approach that it is the etching approach which carries out dry etching of a group III-V semiconducter or the II-VI group compound semiconductor using the mixed gas of the gas and the nitrogen gas containing a halogen with the dry etching system equipped with the source of the plasma which generates the plasma of three or more [about 1010cm -] consistencies, and is (the flow rate of the gas containing a halogen) / (flow rate of nitrogen gas) about >=1, and the pressure under etching reaction is about 1 mTorr or 1 or more mTorrs.
[Claim 2] The etching approach according to claim 1 which accelerates the ion generated in said source of the plasma, and is etched with the kinetic energy of this accelerated ion while heating a sample front face.
[Claim 3] The etching approach according to claim 1 which accelerates the ion generated in said source of the plasma, heats only near the front face of the sample containing an II-VI group compound, and cools the susceptor of this sample with the kinetic energy of this accelerated ion.
[Claim 4] The etching approach according to claim 1 etched while heating sample susceptor.
[Claim 5] the 1st dry etching process which accelerates with the 1st acceleration voltage and etches the ion generated in said source of the plasma -- this -- the 2nd dry etching process which carries out after the 1st dry etching process, accelerates the ion generated in this source of the plasma with the 2nd acceleration voltage, and is etched -- further -- including -- **** -- the etching approach according to claim 1 that this 1st acceleration voltage is larger than this 2nd acceleration voltage.
[Claim 6] The etching approach according to claim 1 which includes the 1st etching process which performs dry etching according to claim 1, and the 2nd etching process which performs wet etching.
[Claim 7] Said dry etching system is the etching approach according to claim 1 of having the source of a radical beam, and the source of an ion beam, and performing dry etching while controlling independently the consistency of the radical generated by this source of a radical beam, and the consistency of the ion generated by this source of an ion beam, respectively.
[Claim 8] Said compound semiconductor is the etching approach according to claim 1 currently formed of AlxGayIn1-x-yP (0< x<=1, 0<=y<=1).
[Claim 9] Said compound semiconductor is the etching approach according to claim 8 currently formed on the off substrate.
[Claim 10] The etching approach which is the etching approach which carries out dry etching of a group III-V semiconducter or the II-VI group compound semiconductor using the mixed gas of the gas and the nitrogen gas containing a halogen with the dry etching system equipped with the source of the plasma which generates the plasma of three or more [about 1010cm -] consistencies, and includes the 1st dry etching process which makes halogen ion density larger than a halogen radical consistency, and etches it, and the 2nd dry etching process which makes halogen ion density smaller than a halogen radical consistency, and is etched.
[Claim 11] The etching system equipped with the reaction chamber linked to the source of a radical beam, the source of an ion beam, and this source of a radical beam and this source of an ion beam, the sample susceptor prepared in this reaction chamber, and a load lock chamber.
[Claim 12] The process which grows at least one compound semiconductor layer epitaxially on a semi-conductor substrate, The process which forms the mask by which patterning was carried out on one compound semiconductor layer even if there is none of these **, The process which etches to one compound semiconductor layer using the etching approach according to claim 1 to 10 even if this ** cannot be found, and forms a ridge stripe using this mask, The manufacture approach of the semiconductor laser component which includes the process which embeds this ridge stripe with a compound semiconductor.
[Claim 13] It is the manufacture approach of a semiconductor laser component given in the claim 12 in which said

substrate is an inclination substrate, said at least one compound semiconductor layer contains in the barrier layer, and the n mold AlGaInP cladding layer and p mold AlGaInP cladding layer which sandwich this barrier layer, and said ridge stripe contains this p mold AlGaInP layer.
[Claim 14] Said p mold AlGaInP cladding layer is the manufacture approach of a semiconductor laser component according to claim 13 that have the 1st cladding layer of p mold AlGaInP, and the 2nd cladding layer of p mold AlGaInP, and the etching stopper layer is formed between this 1st cladding layer and this 2nd cladding layer.
[Claim 15] The manufacture approach of a semiconductor laser component according to claim 14 that the layer for carrying out the monitor of the amount into which this 2nd cladding layer was etched is formed in said 2nd cladding layer of p mold AlGaInP.
[Claim 16] The include angle which it is prepared on the substrate and this substrate, and it is the semiconductor laser component equipped with the ridge stripe containing a barrier layer, and n mold cladding layer which sandwiches this barrier layer and p mold cladding layer, and this ridge stripe has the laser section which carries out laser oscillation, and a taper-like point, and is made with the base of this ridge stripe and the side face of this ridge stripe is an about 60-degree or more semiconductor laser component which is 90 degrees or less.
[Claim 17] It is the semiconductor laser component by which is been the semiconductor laser component equipped with the inclination substrate, and the n mold AlGaInP cladding layer formed on this substrate, a barrier layer and a p mold AlGaInP cladding layer, and this p mold AlGaInP cladding layer has ridge structure with an almost symmetrical configuration, and the current block layer is formed in the both sides of this ridge structure.
[Claim 18] Said p mold AlGaInP cladding layer is a semiconductor laser component according to claim 17 which has the 1st cladding layer of p mold AlGaInP, and the 2nd cladding layer of p mold AlGaInP and by which the etching stopper layer is formed between this 1st cladding layer and this 2nd cladding layer.
[Claim 19] The semiconductor laser component according to claim 18 by which the layer for carrying out the monitor of the amount into which this 2nd cladding layer was etched is formed in said 2nd cladding layer of p mold AlGaInP.
[Claim 20] This width of face that has the width of face to which said point becomes narrower to the shape of a taper than the width of face of said laser section is a semiconductor laser component according to claim 16 which is about 1 micrometer or less.
[Claim 21] Said point is a semiconductor laser component according to claim 16 which has the width of face which becomes larger to the shape of a taper than the width of face of said laser section.

[Translation done.]

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the dry etching approach of a compound semiconductor especially an III-V group, or an II-VI group compound semiconductor, and the semiconductor laser component produced using it.
[0002]
[Description of the Prior Art] There is an approach indicated by JP,7-66175,A as a dry etching technique of the conventional compound semiconductor. By this approach, dry etching is performed to In system compound semiconductor using compound magnetic field mold ECR-RIBE (electron cyclotron resonance-reactivity ion beam etching) equipment. With compound magnetic field mold ECR-RIBE equipment, it has the coil of two functions, a main coil and a subcoil, and emission of the magnetic field near [to etch] a sample is suppressed. According to this approach, chlorine and nitrogen are used as etching gas. A perpendicular cross section and a smooth etching side are acquired [the flow rate of chlorine gas / nitrogen gas] for internal pressure to an etching mask on condition that 0.5mTorr(s) or less to one.
[0003] According to the above-mentioned official report, in chlorine gas / nitrogen gas, when supplying gas at one or less rate, generating of a chlorine radical is controlled and etching by the chlorine ion serves as dominance from a chlorine radical. For this reason, even if it uses the ion which has about teneV low energy, the balance of evaporation of the chloride of In and the chloride of P can be maintained. Consequently, etching from which a perpendicular cross section and a smooth etching side are acquired to an etching mask is realizable.
[0004]
[Problem(s) to be Solved by the Invention] Conventionally, in the dry etching of a compound semiconductor, problems, such as difficulty, had the dry area of the etching side resulting from the difference of the vapor pressure of the reactant of an III group element and etching gas and vapor pressure with the reactant of V group element and etching gas being large, and control of a cross-section configuration.
[0005] The dry etching technique indicated by above-mentioned JP,7-66175,A is also for solving this problem. With this technique, by addition of nitrogen gas, chlorine gas decomposes and the amount of generation of a chlorine radical is controlled by about 1/3 among the chlorine ion generated and the chlorine radical. The above-mentioned problem is solved by this. Moreover, with the above-mentioned technique, in order to make the amount of generation of a chlorine radical into min, the pressure in a reaction chamber is set to 0.5 or less mTorrs. Consequently, the desorption rate of the chloride of In and the chloride of P is balanced. The description of the above-mentioned technique is etching on the conditions from which chlorine radical concentration's becomes min. The above-mentioned official report does not show the quantitive data about the amount of generation and etching property of a chlorine ion.
[0006] Moreover, when aluminum is contained in the sample to etch, there is a problem to which it is no longer etched into or an etching rate falls greatly by aluminum 2O3 being formed of the residual moisture in a reaction chamber.
[0007] The place which this invention is made in view of the above-mentioned situation, and is made into the purpose As opposed to an III-V group and an II-VI group compound semiconductor, and the group III-V semiconducter that contains aluminum further Without reducing the amount of chlorine gas radical formation using the chlorine gas which added nitrogen gas It is in offering the semiconductor laser component which offered the dry etching approach by which a perpendicular cross section and a smooth etching side are acquired, and was produced using this dry etching approach, and its manufacture approach.
[0008]
[Means for Solving the Problem] The etching approach by this invention with the dry etching system equipped with the source of the plasma which generates the plasma of three or more [about 1010cm -] consistencies It is the etching

approach which carries out dry etching of a group III-V semiconducter or the II-VI group compound semiconductor using the mixed gas of the gas and the nitrogen gas containing a halogen. It is (the flow rate of the gas containing a halogen) / (flow rate of nitrogen gas) about >=1, and the pressure under etching reaction is about 1 mTorr or 1 or more mTorrs, and the above-mentioned purpose is attained by that.
[0009] With a certain operation gestalt, the 1st etching process which performs the above-mentioned dry etching, and the 2nd etching process which performs wet etching are included.
[0010] With a certain operation gestalt, the ion generated in said source of the plasma is accelerated, and it etches with the kinetic energy of this accelerated ion, heating a sample front face.
[0011] With a certain operation gestalt, the ion generated in said source of the plasma is accelerated, with the kinetic energy of this accelerated ion, it heats only near the front face of the sample containing an II-VI group compound, and the susceptor of this sample is cooled.
[0012] It etches with a certain operation gestalt, heating sample susceptor.
[0013] the 1st dry etching process which accelerates with the 1st acceleration voltage and etches the ion generated in said source of the plasma with a certain operation gestalt -- this -- it carries out after the 1st dry etching process, and the ion generated in this source of the plasma is accelerated with the 2nd acceleration voltage, the 2nd dry etching process to etch is included further, and this 1st acceleration voltage is larger than this 2nd acceleration voltage.
[0014] With a certain operation gestalt, said dry etching system is equipped with the source of a radical beam, and the source of an ion beam, and it performs dry etching, controlling independently the consistency of the radical generated by this source of a radical beam, and the consistency of the ion generated by this source of an ion beam, respectively.
[0015] With a certain operation gestalt, said compound semiconductor is formed of AlxGayIn1-x-yP (0< x<=1, 0<=y<=1).
[0016] With a certain operation gestalt, said compound semiconductor is formed on the off substrate.
[0017] Other etching approaches by this invention with the dry etching system equipped with the source of the plasma which generates the plasma of three or more [about 1010cm -] consistencies It is the etching approach which carries out dry etching of a group III-V semiconducter or the II-VI group compound semiconductor using the mixed gas of the gas and the nitrogen gas containing a halogen. The 1st dry etching process which makes halogen ion density larger than a halogen radical consistency, and etches it, Halogen ion density is made smaller than a halogen radical consistency, the 2nd dry etching process to etch is included and the above-mentioned purpose is attained by that.
[0018] The etching system by this invention is equipped with the reaction chamber linked to the source of a radical beam, the source of an ion beam, and this source of a radical beam and this source of an ion beam, the sample susceptor prepared in this reaction chamber, and a load lock chamber, and the above-mentioned purpose is attained by that.
[0019] The manufacture approach of the semiconductor laser component by this invention The process which grows at least one compound semiconductor layer epitaxially on a semi-conductor substrate, The process which forms the mask by which patterning was carried out on one compound semiconductor layer even if there is none of these **, The process which etches to one compound semiconductor layer using the etching approach according to claim 1 to 10 even if this ** cannot be found, and forms a ridge stripe using this mask, The process which embeds this ridge stripe with a compound semiconductor is included, and the above-mentioned purpose is attained by that.
[0020] With a certain operation gestalt, said substrate is an inclination substrate, said at least one compound semiconductor layer contains the barrier layer, and the n mold AlGaInP cladding layer and p mold AlGaInP cladding layer which sandwich this barrier layer, and said ridge stripe contains this p mold AlGaInP layer.
[0021] With a certain operation gestalt, said p mold AlGaInP cladding layer has the 1st cladding layer of p mold AlGaInP, and the 2nd cladding layer of p mold AlGaInP, and the etching stopper layer is formed between this 1st cladding layer and this 2nd cladding layer.
[0022] With a certain operation gestalt, the layer for carrying out the monitor of the amount into which this 2nd cladding layer was etched is formed in said 2nd cladding layer of p mold AlGaInP.
[0023] The semiconductor laser component by this invention is prepared on the substrate and this substrate. A barrier layer, It is the semiconductor laser component equipped with the ridge stripe containing n mold cladding layer which sandwiches this barrier layer, and p mold cladding layer. This ridge stripe It has the laser section which carries out laser oscillation, and a point, the base of this ridge stripe, the side face of this ridge stripe, and the include angle to make are about 60 degrees or more 90 degrees or less, and the above-mentioned purpose is attained by that.
[0024] With a certain operation gestalt, said point has the width of face which becomes thin in the shape of a taper from the width of face of said laser section, and this width of face is about 1 micrometer or less.
[0025] With a certain operation gestalt, said point has the width of face which becomes larger to the shape of a taper than the width of face of said laser section.

[0026] Other semiconductor laser components by this invention are semiconductor laser components equipped with the inclination substrate, and the n mold AlGaInP cladding layer formed on this substrate, a barrier layer and a p mold AlGaInP cladding layer, this p mold AlGaInP cladding layer has ridge structure with an almost symmetrical configuration, the current block layer is formed in the both sides of this ridge structure, and the above-mentioned purpose is attained by that.
[0027] With a certain operation gestalt, said p mold AlGaInP cladding layer has the 1st cladding layer of p mold AlGaInP, and the 2nd cladding layer of p mold AlGaInP, and the etching stopper layer is formed between this 1st cladding layer and this 2nd cladding layer.
[0028] With a certain operation gestalt, the layer for carrying out the monitor of the amount into which this 2nd cladding layer was etched is formed in said 2nd cladding layer of p mold AlGaInP.
[0029]
[Embodiment of the Invention] Below, the operation gestalt of this invention is explained at a detail.
[0030] (1st operation gestalt) As 1st operation gestalt of the dry etching approach by this invention, the dry etching approach for a group III-V semiconducter is explained. InP is used as a sample to etch. Chlorine gas and nitrogen gas are used as etching gas. Drawing 1 shows the configuration of the ECR-RIBE equipment (it is called ECR-RIBE equipment for short electron cyclotron resonance-reactivity ion beam etching and the following) used with this operation gestalt in ** type. In this equipment, the location of the sample to etch is located on the outside of the coil which generates a magnetic field.
[0031] As shown in drawing 1 , ECR-RIBE equipment is connected with ECR source 101 and the ECR source, and is mainly equipped with the reaction chamber 102 and exhaust air pump system (not shown) for installing a sample. Ion and a radical are generated in ECR source 101. From a gas inlet 108, the chlorine gas and the nitrogen gas by which the flow rate was controlled are introduced into ECR source 101. Furthermore, 2.45GHz microwave will face the quartz aperture 107, and will be introduced into ECR source 101, and chlorine gas and nitrogen gas will be from a waveguide 106 in an excitation state. An electron sympathizes with the 875 gauss magnetic field generated with the coil 103, and it repeats gas and a collision, carrying out the circular motion. In this way, it is accelerated by the grid 104 and the chlorine ion and nitrogen ion which were generated in ECR source 101 are irradiated by the sample 105.
[0032] Although it is accelerated and a chlorine ion and nitrogen ion are irradiated by the sample 105, since it is not ionized, the chlorine radical and nitrogen radical which are generated in ECR source 101 are not accelerated. However, a chlorine radical and a nitrogen radical arrive at the front face of a sample 105 by diffusion, and contribute to etching. As for this ECR-RIBE equipment, unlike the compound magnetic field mold, the coil is not installed in the side face of a reaction chamber 102. For this reason, the magnetic field generated with a coil 103 is an emission magnetic field.
[0033] The ion and radical which were produced as mentioned above arrive at sample 105 front face, react with InP which is a sample, and In chloride and P chloride generate them. The boiling point of PCl_3 has the boiling point of 76 degrees C and PCl_5 as low as 162 degrees C, and evaporates P chloride easily.
[0034] On the other hand, the boiling point of 560 degrees C and $InCl_3$ has the boiling point of 608 degrees C and $InCl_2$ as high as 600 degrees C, and the boiling point of InCl cannot evaporate In chloride easily. For this reason, the layer of In chloride is formed in the front face of a sample 105. Since evaporation of In chloride is promoted, the acceleration voltage of ion serves as an important element, because the chlorine ion and nitrogen ion which were accelerated collide with the front face of a sample 105 from ECR source 101. Less than [acceleration voltage 300V], evaporation does not take place and In chloride is not etched.
[0035] Table 1 shows the conditions of etching of being used with this operation gestalt.
[0036]
[Table 1]

塩素	窒素	マイクロ波パワー	加速電圧	内圧	試料温度
3~20 SCCM	3.5~35 SCCM	200W(固定)	300~900 V	0.5~2.5 mTorr	室温 -300℃

[0037] In the conditions shown in Table 1, acceleration voltage is about 300v or more, and etching is the optimal. In addition, SiO_2 is used as a mask for etching.
[0038] The main results of having performed dry etching to below using the conditions shown in Table 1 are explained.
[0039] In the experiment, the chlorine flow rate was set as about 10 SCCM(s), about 2.5 mTorr(s) and sample temperature were set [acceleration voltage] as about 200 degrees C for the internal pressure under about 650V and reaction, the nitrogen flow rate was changed, and dry etching was performed. Evaporation of an III group compound can

be promoted by heating sample susceptor and maintaining sample temperature at about 200 degrees C.
[0040] As a nitrogen flow rate, drawing 2 shows each cross-section photograph of InP to which about 35 SCCM(s) and drawing 3 performed about 7 SCCM(s) on condition that about 3.5 SCCM(s), and drawing 4 performed dry etching in a mimetic diagram.
[0041] Drawing 2 (a) shows the cross section etched using SiO2 mask to an InP substrate. Although InP is etched as shown in this drawing, the base (etching side) is very ruined. Drawing 2 (b) is the perspective view of drawing 2 (a). Drawing 2 (b) also shows well that the base is ruined. In the case of drawing 3 , etching is possible in the almost perpendicular direction to SiO2 mask, and most base dry areas are lost. In the case of drawing 4 , there is no base dry area and the etching side is smooth. However, side etching into which the mask bottom is also etched takes place, and perpendicular etching has not been performed to the mask.
[0042] The above-mentioned result shows that there is a boundary where the etching side of nitrogen flow rate [a chlorine flow rate /] is ruined between about 0.29 and 1.43. According to the experiment, it turned out that the ratios of the chlorine flow rate / nitrogen flow rate of the boundary are the about 1.0 neighborhoods. Moreover, it turns out that the smooth nature of an etching side has [the about 2.85 neighborhoods] the best ratio of a chlorine flow rate / nitrogen flow rate.
[0043] However, if the cross-section configuration of drawing 4 is seen, it is not perpendicular and side etching is considerably contained. In order to obtain a perpendicular cross section, it is necessary to stop the chemical reaction component in dry etching. Then, it etched by lowering sample temperature to about 100 degrees C. The result is shown in drawing 5 (conditions other than temperature are the same as the case of drawing 4). [0044] By lowering sample temperature to 100 degrees C, a spatter component will become strong from chemical reactivity, and SiO2 mask will retreat by being etched (it moves to a substrate side). For this reason, over etching happens and it becomes a trapezoid cross-section configuration. However, since the etching side is very smooth, it is satisfactory practically also in a trapezoid cross section.
[0045] As shown in drawing 4 and 5, when the chemical reaction component in etching is more superior than a spatter component, side etch happens, when a spatter component is more superior than chemical reactivity, a mask retreats and over-etching happens.
[0046] Next, examination of the etching conditions for obtaining a perpendicular cross section is explained.
[0047] In order to make chemical reactivity increase, sample temperature was made into about 150 degrees C, in order to raise an etching rate, the amount of supply of chlorine was increased up to about 11.5 SCCM(s) (a nitrogen flow rate is 3.5SCCM(s) as well as the case of drawing 4), and it etched. The result is shown in drawing 6 . A spatter component and a chemical reaction component can be balanced and a perpendicular etching cross section is realized so that drawing 6 may show. In this case, acceleration voltage is about 650V and internal pressure is still about 2.5 mTorr(s).
[0048] Each etching condition in drawing 2 -6 is collectively shown in Table 2.
[0049]
[Table 2]

	塩素 (SCCM)	窒素 (SCCM)	塩素/窒素 流量比	加速電圧 (V)	内圧 (mTorr)	試料温度 (℃)
図2	10	35	0.29	650	2.5	200
図3	10	7	1.43	650	2.5	200
図4	10	3.5	2.8	650	2.5	200
図5	10	3.5	2.8	650	2.5	100
図6	11.5	3.5	3.29	650	2.5	150

[0050] It will not be ruined if the ratio of a chlorine flow rate / nitrogen flow rate is about 1.0 or more. However, if this flow rate is made large to 6.4 or more, it will begin to be ruined for a while again. In consideration of the dry area of an etching side, the range of the optimum value of the flow rate of a chlorine flow rate / nitrogen flow rate is about 1.0 to 6.4.
[0051] drawing 16 -- the spectrum of plasma luminescence -- a result is shown. An optical result expresses a change of the nitrogen ion and chlorine ion to nitrogen concentration, and a chlorine radical on the strength at this rate. Each luminescence reinforcement shown in drawing 16 is standardized by the plasma luminescence reinforcement of only chlorine gas. As for nitrogen ion, 652.9nm was observed, and, as for the chlorine ion, luminescence by 727.9nm was observed, as for 450.8nm and a chlorine radical. Luminescence by 652.9nm only in the case of chlorine gas is a noise,

and is not luminescence by nitrogen ion.
[0052] The luminescence reinforcement of nitrogen ion increases simply in proportion to the addition of nitrogen. Although the luminescence reinforcement by the chlorine ion increases by addition of nitrogen, the addition concentration of nitrogen shows maximum at about 23%. This maximum is about 1.4 times in nitrogen additive-free. Then, according to the increment in nitrogen addition concentration, slight luminescence reinforcement by the chlorine ion decreases, and is saturated with one about 1.3 times [in nitrogen additive-free] the value of this. although it increases about 10% by addition of nitrogen, it comes out to this extent and the luminescence reinforcement by the chlorine radical is saturated, and even if it adds nitrogen further, it does not increase.
[0053] Below, change of the above-mentioned luminescence reinforcement is explained as compared with an etching property.
[0054] When a chlorine flow rate / nitrogen flow rate is less than one, the nitrogen concentration in drawing 16 is a field (field **) exceeding 50%. In field **, although chlorine ion reinforcement is about 1.3 or more times to the case of pure chlorine (nitrogen additive-free), nitrogen ionic strength has increased about 3 times. That is, it is thought with superfluous nitrogen ion by carrying out the spatter of the P chloride with vapor pressure high among In chloride and P chloride alternatively that it is ruined.
[0055] When a chlorine flow rate / nitrogen flow rate is 6.4 or less [about 1 or more], the nitrogen concentration of drawing 16 is equivalent to about 50% or less of field (field **) about 13% or more. In this field, the reinforcement of nitrogen ion does not increase so much, but balance of the desorption from the front face of In chloride and P chloride can be taken, and the smooth etching side is realized.
[0056] When a chlorine flow rate / nitrogen flow rate exceeds 6.4, the nitrogen concentration of drawing 16 is equivalent to about 13% or less of field (field **). In field **, it is ruined again. Since the desorption of In chloride which this generated, and P chloride mainly happens with heat energy from the spatter effectiveness, it is thought that it is because the alternative desorption of P chloride happens.
[0057] As stated above, the effectiveness which adds nitrogen gas not only promotes generation of a chlorine ion, but in this invention, the big description has it in the place which promotes the desorption of the chloride of an III group or V group according to the spatter effectiveness by the nitrogen ion itself. This is also the same as when this invention is applied to an II-VI group compound semiconductor.
[0058] In the above explanation, as an ingredient to etch, although a group's III-V semiconducter InP was used, the ingredient of an AlGaInP system, an AlGaInN system, and the ZnMgSSe system of an II-VI group compound semiconductor may be used instead of InP so that it may explain later. Moreover, although an etching rate falls, etching is possible even if it holds substrate temperature to a room temperature.
[0059] (2nd operation gestalt) Below, the dry etching approach for a group III-V semiconducter is explained as 2nd operation gestalt of the dry etching approach by this invention. More specifically, the dry etching approach to etch is explained with the kinetic energy of the accelerated ion, heating only a sample front face, without raising the temperature of the whole sample.
[0060] InP is used as an etching sample and SiO2 is used as an etching mask. In addition, the approach of this operation gestalt is applicable to etching of an II-VI group compound semiconductor.
[0061] As the operation gestalt of the above 1st described, when raising sample temperature, the chemical reaction component in dry etching becomes dominance from a spatter component, and side etching into which the mask bottom is also etched takes place. However, if sample temperature is lowered, since a spatter component will become strong, over-etching to which a mask retreats is caused, or an etching base is ruined.
[0062] So, with this operation gestalt, it is made to stick to the sample maintenance fixture which produced the sample with aluminum, and it etches, cooling this maintenance fixture.
[0063] By the grid, it is accelerated by hundreds V and the ion generated in an ECR source is irradiated by the sample with kinetic energy. The radical generated in an ECR source is not accelerated. Since the energy per radical has many radicals generated with 20-30eV although it is small, the total energy received from a radical has a quite large sample front face. Thus, in order that a sample front face may obtain many ion and the energy of a radical, even if it does not go up the temperature of a sample substrate, the same effectiveness as the case where the sample itself is raised to hundreds of degrees C is acquired. That is, by heating the front face of a sample in this way, evaporation of the chloride of an III group or II group is promoted, and an etching rate is improved.
[0064] ECR-RIBE equipment is used, about 200W and internal pressure are set to about 2.5 mTorr(s), it sets [a chlorine flow rate / about 11.5 SCCM(s) and a nitrogen flow rate] acceleration voltage to about 650 V for about 3.5 SCCM(s) and microwave power, and drawing 8 shows the cross section of InP at the time of performing dry etching to InP.
[0065] In this case, it is not heating to the whole sample. The sample maintenance fixture produced with aluminum is

equipped with the sample. A sample maintenance fixture is put on the sample susceptor by which water cooling was carried out. Only the part near the front face of a sample is heated by this, and the temperature of the part except this part does not rise by it. A sample is protected from a thermal damage. Especially the thing done like this is effective in etching the sample containing an II-VI group compound. Because, since the crystal growth temperature (about 260 degrees C) of an II-VI group compound semiconductor is low, in order to prevent crystalline degradation, it is necessary to make etching temperature lower (about 250 degrees C or less) than crystal growth temperature.

[0066] As the operation gestalt of the above 1st described, the configuration of an etching cross section reflects the balance of the spatter component to etch and a chemical reaction component. That is, when a spatter component is dominance, over-etching of the cross section is carried out, and when a chemical reaction component is dominance, side etching takes place.

[0067] Although the temperature of the whole sample is near a room temperature according to this operation gestalt as drawing 8 shows, the cross section is almost perpendicular and has balanced the chemical reaction component and the spatter component. The cross section of drawing 8 shows the same cross-section configuration as the case of drawing 6 , when it etches by setting sample temperature as 150 degrees C. That is, the result shown in drawing 8 which etched without heating is the same as the result shown in drawing 6 which etched by setting sample temperature as 150 degrees C about the cross-section configuration. However, the etching rate in the case of drawing 8 is lower than it in the case of drawing 6 25%.

[0068] In addition, with this operation gestalt, although sample temperature is set up near the room temperature, it can also make the difference [chloride / of an III group] of sublimation small by cooling sample susceptor at 0 degree C or less, and controlling sublimation of V group's chloride. This can perform dry etching from which a perpendicular cross section and a smooth etching side are acquired.

[0069] (3rd operation gestalt) As 3rd operation gestalt of the dry etching approach by this invention, the dry etching approach for a group III-V semiconducter is explained. The dry etching approach of more specifically performing two steps of etching of different conditions is explained. As a sample, SiO2 is used as InP and an etching mask, and chlorine and nitrogen are used as etching gas.

[0070] The 1st dry etching is first performed using ECR-RIBE equipment. In this 1st dry etching, by setting internal pressure to about 1 or less mTorr, and setting acceleration voltage to about 300v or more, the collision between gas molecules is suppressed and ion density is made larger than a radical consistency. About 1 or more and sample temperature are set as about 100 degrees C for a chlorine flow rate / nitrogen flow rate. In this case, etching by the spatter component becomes dominance from a chemical reaction component, the high-speed dry etching in a perpendicular direction progresses to a sample front face, and the configuration near a desired configuration is formed.

[0071] The 1st dry etching of the above has the above and a comparatively high etching rate by about 1000A/. When etching at high speed, in the etched side face or etching side, the damage by which induction is carried out to processing arises, or it is ruined. This is because a crystal defect arises in a sample, when it is accelerated on the high electrical potential difference beyond 300V and the halogen ion generated in an ECR source is irradiated by the sample. Moreover, since the boiling points of a halogenide differ to an III group (or II group) and V groups (or VI group), when the stoichiometry in an etching side shifts, it is because the III group (or II group) elements in an etching side increase in number more than V group (or VI group) element in an excess.

[0072] Next, it continues at the 1st dry etching and the 2nd dry etching is performed. It is removing the layer which has the processing induction damage produced by the 1st dry etching as a purpose which performs this 2nd dry etching. Moreover, it is removing the devastated field and making it smooth by the 1st dry etching, when a dry area's arises in an etching side. In order to attain the above-mentioned purpose, about 3 or more and internal pressure are set as about 2 or more mTorrs, it sets about 300v or less and sample temperature as about 200 degrees C for acceleration voltage, and the 2nd dry etching performs a chlorine flow rate / nitrogen flow rate. In this case, the collision between gas molecules increases and the radical consistency becomes large from ion density. Furthermore, since a mean free path becomes small, the chemical reaction component acts strongly from a spatter component.

[0073] Since the processing induction damage done to a crystal is small, etching under the strong conditions of the above chemical reactivity can remove a layer including many processing induction damages produced in the 1st dry etching. When ruined in the 1st dry etching, the devastated field can be made smoother by the 2nd dry etching of the above.

[0074] The 1st dry etching is a chlorine flow rate. Although it can carry out on condition that /nitrogen flow rate abbreviation >=1, internal pressure abbreviation <=1mTorr, and acceleration voltage abbreviation >=300V, a chlorine flow rate / nitrogen flow rate abbreviation >=3, internal pressure abbreviation <=0.5mTorr, and acceleration voltage abbreviation >=600V are more more desirable as optimum conditions.

[0075] Although the 2nd dry etching can be performed on condition that a chlorine flow rate / nitrogen flow rate

abbreviation>=3, internal pressure abbreviation >=2mTorr, and acceleration voltage abbreviation <=300V, a chlorine flow rate / nitrogen flow rate abbreviation >=10, internal pressure abbreviation >=3mTorr, and acceleration voltage abbreviation <=100V are more more desirable as optimum conditions.

[0076] Drawing 12 is the sectional view showing the process of the dry etching by this operation gestalt. First, as shown in drawing 12 (a), SiO2 mask 1202 by which patterning was carried out is formed on the InP substrate 1201. Then, as shown in drawing 12 (b), the 1st dry etching is performed. According to this process, the damage layer 1203 by which induction is carried out to processing arises on an etching front face. Next, as shown in drawing 12 (c), the 2nd dry etching is performed. In the 2nd dry etching, a chlorine ion consistency is small and a chlorine radical consistency is larger than the case of the 1st dry etching. By performing the 2nd dry etching, the damage layer 1203 by which induction is carried out to processing is removed, and a perpendicular side face and a smooth etching side can be formed to a mask 1202.

[0077] In addition, in the above explanation, the size relation of the chlorine ion consistency and chlorine radical consistency in the 1st and 2nd dry etching was changed by changing internal pressure, flow rate, and acceleration voltage. Instead, the 1st and the 2nd dry etching may be performed by changing only acceleration voltage. That is, the 1st and 2nd dry etching is a chlorine flow rate. Using conditions with /nitrogen flow rate abbreviation >=3, an internal pressure abbreviation >=2mTorr, and a sample temperature of about 200 degrees C, in the 1st dry etching, acceleration voltage is set as about 900V, and acceleration voltage is set as about 100 V by the 2nd dry etching. On such conditions, even if it performs dry etching, etching without a dry area is realizable.

[0078] (4th operation gestalt) Below, the etching approach for a group III-V semiconducter is explained as 4th operation gestalt of the etching approach by this invention. More specifically, the etching approach of performing two steps of etching, dry etching and wet etching, is explained. As a sample, SiO2 is used as InP and an etching mask, and chlorine and nitrogen are used as etching gas. As an etching solution of wet etching, a hydrochloric acid, an acetic acid, and hydrogen peroxide solution are used.

[0079] First, 1st etching (dry etching) is performed using ECR-RIBE equipment. In this 1st etching, abbreviation >=1 and internal pressure are made to about 2 or more mTorrs, and about 300v or more and sample temperature are made [a chlorine flow rate / nitrogen flow rate] into about 100 degrees C or more for acceleration voltage. Although the 1st etching is possible on the above-mentioned conditions, for about 3.5 SCCM(s) and sample temperature, about 150 degrees C and acceleration voltage are [a chlorine flow rate / about 11.5 SCCM(s) and a nitrogen flow rate / about 650V and internal pressure of optimum conditions] about 2.5 mTorr(s). On such conditions, a sample is processible into a predetermined configuration. A layer including the processing induction damage generated by the 1st etching is removed by the 2nd etching explained below.

[0080] Drawing 7 shows typically the configuration of the spin etching system used for the 2nd etching. 2nd etching, i.e., wet etching, is performed in a reaction chamber 705. The sample 701 by which dry etching was carried out [above-mentioned] is installed on the sample maintenance base 702. The sample maintenance base 702 holds a sample 701 by the vacuum chuck, and rotates with a predetermined rotational speed. The mixed liquor of the hydrochloric acid which is maintained by the etchant tank 704 and saved to predetermined temperature at it, an acetic acid, and hydrogen peroxide solution comes out of a nozzle 703, and flows and falls on a sample 701. The core of a nozzle 703 and the sample maintenance base 702 is in agreement, and a nozzle 703 reciprocates the between to a predetermined distance to radial [of the core of the sample maintenance base 702 to a sample maintenance base]. While a nozzle 703 fails to flow liquid in the sample 701 to rotate, very uniform wet etching is performed by reciprocating radial. In this way, the damage layer by which induction is carried out to processing produced by the 1st etching is removed. The temperature of 3:36:1 and mixed liquor of the mixing ratio of a hydrochloric acid, an acetic acid, and hydrogen peroxide solution should just be 20 degrees C.

[0081] Since wet etching does not contain a spatter component, some damages which are given by using dry etching can also be prevented by using wet etching. For this reason, the smooth nature of an etching side can be improved further.

[0082] In this operation gestalt, as a solution used for the 2nd etching, although a hydrochloric acid, an acetic acid, and hydrogen peroxide solution were used, it may replace with this and the mixed liquor of the mixed liquor of the mixed liquor of a sulfuric acid, hydrogen peroxide solution, and water, a hydrochloric acid, and a phosphoric acid or saturation bromine water, and a methanol may be used. What is necessary is just the solution from which induction is carried out to processing produced by the 1st etching in short, and a damage layer can be removed.

[0083] (5th operation gestalt) The dry etching system which equipped below with the source of a radical beam and the source of an ion beam other than an ECR source, and the dry etching approach using it are explained.

[0084] Drawing 9 shows typically the configuration of the dry etching system of this operation gestalt. This equipment is equipped with the source 902 of a radical beam and the source 903 of an ion beam other than ECR source 904 and a

reaction chamber 901. The source 902 of a radical beam and the source 903 of an ion beam are connected to the reaction chamber 901.

[0085] All over the reaction chamber 901, it has the sample maintenance base 905 holding a sample 906. The chlorine ion generated by the chlorine radical generated in the source 902 of a radical beam, the chlorine ion generated in the source 903 of an ion beam, and ECR source 904, a chlorine radical, and nitrogen ion are irradiated by the sample 906. A sample 906 is sent to a reaction chamber 901 from the load lock chamber 900 for paying a sample 906 to a reaction chamber 901. A reaction chamber 901 is exhausted by about 10 to 6 or less Torrs by the exhaust air system (not shown).

[0086] In the source 902 of a radical beam, RF RF will be added and chlorine gas will be in the plasma state. A chlorine ion and a chlorine radical occur by this. Since a mean free path is several centimeters, it collides with other atoms or an electron and a chlorine ion disappears in the source 902 of a radical, or a reaction chamber 901 when not accelerated, it does not reach to a sample. The generated radical arrives even at a sample front face by diffusion, and contributes to a reaction.

[0087] On the other hand, also in the source 903 of an ion beam, RF RF will be added and chlorine gas will be in the plasma state. A chlorine ion and a chlorine radical occur by this. By changing the electrical potential difference applied to the drawer electrode 9031, by changing the rate of the chlorine ion pulled out from the source 903 of an ion beam, and a chlorine radical, many chlorine ions are pulled out and irradiated on a sample front face from a chlorine radical.

[0088] In ECR source 904, as the 1st operation gestalt described, gas is decomposed and ion and a radical are generated. Nitrogen gas is introduced into ECR source 904 in this operation gestalt.

[0089] The consistency of the radical which contributes to the smooth nature of the gas which contributes to a reaction, and the consistency of the ion contributed to an etching rate are independently controllable, respectively by having the ion source, a source of a radical, and an ECR source as mentioned above. For this reason, high-speed etching is possible, with the smooth nature of an etching side maintained. It becomes easy to control the smooth nature of an etching rate, a cross-section configuration, and an etching side. As the 1st operation gestalt described in the case of the dry etching of InP by the mixed gas of chlorine and nitrogen, using SiO2 as a mask, P chloride is sublimated easily, and since it is hard to sublimate In chloride, the layer of In chloride will be formed in a sample front face. What is necessary is just to use the kinetic energy of the accelerated chlorine ion and nitrogen ion, in order to make the layer of this In chloride sublimate.

[0090] Then, what is necessary is to make [more] a chlorine ion flow rate than a chlorine radical flow rate, to accelerate by the high voltage of about 300v or more, and just to supply a chlorine ion and nitrogen ion. What is necessary is just to set sample temperature as about 150 degrees C or more, in order to make an etching rate high.

[0091] According to this operation gestalt, the dry etching of InP in which about 300v or more and the nitrogen ion from an ECR source are [about 10 or more SCCMs and acceleration voltage] about 3 or less SCCMs for the chlorine ion flow rate from about 1 or more SCCMs and the source of an ion beam, and the chlorine radical flow rate from the source of a radical beam has a smooth etching side is possible. Furthermore, dry etching in which a chlorine radical flow rate has the cross section about 1 SCCM and a chlorine ion flow rate has [the acceleration voltage of about 10 SCCM(s) and a chlorine ion / about 600v or more and the nitrogen flow rate of an ECR source] about 3 SCCM(s) and sample temperature perpendicular in a cross section on the conditions which are about 150 degrees C, and a smooth etching side is realized.

[0092] (6th operation gestalt) Below, the manufacture approach of a semiconductor laser component is explained using the etching approach explained with the operation gestalt of the above 1-5ths. The diameter conversion laser of a spot is used as a semiconductor laser component. Drawing 10 (a) - (c) shows typically the cross section of the structure of the diameter conversion laser of a spot.

[0093] This diameter conversion laser of a spot has the laser section 1010 and the spot-size transducer (point) 1011, as shown in drawing 10 (a). The laser section 1010 has the stripe configuration which has fixed width of face and thickness. As for the spot-size transducer 1011, width of face is [width of face] small toward the outgoing radiation edge 1012 at the shape of a taper. A laser beam is changed into the path m of the outgoing radiation edge (tip of a point 1011) 1012 of the spot-size transducer 1011 from the diameter of a spot in the laser section 1010, while guiding the spot-size transducer 1011. Width of face m is [the include angle of about 1 micrometer or less (typically about 0.6 micrometers) and a cross section of the outgoing radiation edge 1012] about 90 degrees.

[0094] Drawing 10 (b) shows the cross section in alignment with line A-A' of drawing 10 (a). As shown in drawing 10 (b), epitaxial growth of the n-InP layer 1002, the n-InGaAsP cladding layer 1003, a barrier layer 1004, the p-InGaAsP cladding layer 1005, and the p-InP cap layer 1007 is carried out one by one on the n-InP substrate 1001. these layers -- the mesa stripe (ridge stripe) 1014 -- constituting -- the mesa stripe 1014 -- half--- it is embedded by insulating InP1006. The p lateral electrode 1009 is formed on the p-InP cap layer 1007, and the n lateral electrode 1008 is formed all over the rear face of a substrate 1001.

[0095] The electron hole poured in from the p lateral electrode 1009 is recombined by the electron and barrier layer 1004 which were poured in from the n lateral electrode 1008. Luminescence takes place under the p lateral electrode 1009, and carries out laser oscillation by being shut up in a resonator end face.
[0096] Drawing 10 (c) shows the cross section in alignment with line B-B' of drawing 10 (a). The laser section 1010 differs in the width of face of a barrier layer 1004 from the spot-size transducer 1011 so that drawing 10 (b) and drawing 10 (c) may be compared and understood. That is, the direction of the width of face of the barrier layer 1004 of the spot-size transducer 1011 is small.
[0097] Below, the manufacture approach of the diameter conversion laser of a spot is shown, referring to drawing 11 (a) - (g). Drawing 11 (a) - (g) is the mimetic diagram of the cross section of the laser section 1010. The width of face of a barrier layer etc. only differs, and the spot-size transducer 1011 is manufactured by the laser section 1010 and coincidence.
[0098] First, as shown in drawing 11 (a), sequential growth of the n-InP layer 1102, the n-InGaAsP cladding layer 1103, a barrier layer 1104, and the p-InGaAsP cladding layer 1105 is carried out on the n-InP substrate 1101 by metal-organic chemical vapor deposition (MOVPE law). Then, as shown in drawing 11 (b), SiO2 mask 1106 which has a predetermined configuration is formed on the p-InGaAsP cladding layer 1105.
[0099] Next, as shown in drawing 11 (c), the mesa stripe (ridge stripe) 1109 is formed using ECR-RIBE equipment by the etching approach explained with the operation gestalt of the above 1-5ths. Chlorine flow rate / nitrogen flow rate abbreviation >=1, and microwave power about 200W, the internal pressure of about 2 or more mTorrs, the sample temperature of about 150 degrees C or more, and the acceleration voltage of the conditions of etching are about 300v or more. The side face of a mesa stripe and the front face of a substrate 1101 which are formed on this condition, and the include angle theta to make are about 60 degrees or more 90 degrees or less, as shown in drawing 11 (c) and (g). next, it is shown in drawing 11 (d) -- as -- MOVPE -- law -- SiO2 mask 1106 -- as the mask of selective growth -- using -- crystal growth -- carrying out -- the mesa stripe 1109 -- half--- it embeds by insulating InP1107. after removing SiO2 mask 1106, it is shown in drawing 11 (e) -- as -- MOVPE -- the p-InGaAsP cap layer 1108 is grown up by law. Finally, as shown in drawing 11 (f), it heat-treats by vapor-depositing the p lateral electrode 1111 and the n lateral electrode 1110, and ohmic contact is formed.
[0100] As explained above, according to this invention, a cavity and waveguide with the front face of the substrate 1101 as shown in drawing 11 (g), the side attachment wall of the mesa stripe whose include angle theta to make is about 60 degrees - 90 degrees, and outgoing radiation opening of 1 micrometer or less of **** can be formed by etching with ECR-RIBE equipment using chlorine gas and nitrogen gas. According to the approach of this invention, it is avoidable that the reverse mesa (the above-mentioned include angle theta is 90 degrees or more) to which the dependability of a component is fallen is formed.
[0101] In addition, in the above-mentioned explanation, although the width of face of a point 1011 is narrower to the shape of a taper than the width of face of the laser section 1010, it may become larger to the shape of a taper than the width of face of the laser section 1010.
[0102] In the above operation gestalt, although ECR-RIBE equipment was used, it may replace with this and the dry etching system equipped with the source of the inductive-coupling mold plasma, the dry etching system equipped with the source of the Helicon mold plasma, or the dry etching system equipped with the source of the NLD mold plasma may be used.
[0103] Moreover, although the above operation gestalt explained using InP as a compound semiconductor, other III-V groups or II-VI group compound semiconductors may be used. In addition, in the above explanation, although chlorine gas was used, the gas containing chlorine, a bromine, or iodine may be used.
[0104] (7th operation gestalt) Below, the manufacture approach of other semiconductor laser components is explained using the etching approach explained with the operation gestalt of the above 1-5ths, referring to drawing 13 (a) - (d). In this operation gestalt, the compound semiconductor etched contains aluminum (aluminum).
[0105] first, it is shown in drawing 13 (a) -- as -- MOVPE -- on the n mold GaAs substrate 1301 by law A n mold GaAs buffer layer (un-illustrating), n mold AlxGayIn1-x-yP (0< x<=1, 0<=y<=1, and the following) AlGaInP The cladding layer 1302 called for short, the multiplex quantum well barrier layer 1303 constituted by an AlGaInP barrier layer and the GaInP well layer, the 1st cladding layer 1304 of p mold AlGaInP, the GaInP etching stopper layer 1305 (thickness: about 5nm), Epitaxial growth of the 2nd cladding layer 1306 of p mold AlGaInP is carried out. The GaAs substrate 1301 is an off substrate which inclines in the [110] directions about 10 degrees from the field (100).
[0106] Next, in order to form a ridge, 4 micrometers of **** and SiO2 mask 1307 with a thickness of about 0.5 micrometers by which patterning was carried out are formed on the p mold AlGaInP layer 1306.
[0107] Next, as shown in drawing 13 (b), a ridge 1313 is formed by using SiO2 mask 1307 as an etching mask using the

dry etching approach explained by the above 1-5ths. As conditions for etching, a chlorine flow rate / nitrogen flow rate is set as about 3.1 by setting a chlorine flow rate to about 11 SCCM(s), and setting nitrogen to about 3.5 SCCM(s). In addition, acceleration voltage is [about 2.5 mTorr(s) and the sample temperature of about 650V and internal pressure] about 100 degrees C. The ridge 1313 of symmetrical trapezoidal shape is obtained by performing dry etching on such conditions.

[0108] Usually, by etching using an inclination substrate, as shown in drawing 14 (b), a ridge does not become the configuration of bilateral symmetry. Since the substrate inclines from a field (100), in the wet etching using the etching reagent of a sulfuric-acid system, the inclination of the side face in the pars basilaris ossis occipitalis of a ridge becomes loose, and a ridge serves as an unsymmetrical configuration. Consequently, impregnation of the carrier to a barrier layer and light close, eye ** becomes an ununiformity, and the transverse mode becomes unstable. This becomes remarkable when operating laser at an elevated temperature especially.

[0109] Moreover, in the semiconductor laser of an AlGaInP system, in order to short-wavelength-ize wavelength of a laser beam, whenever [tilt-angle] is enlarged increasingly. The asymmetry of a ridge becomes larger as whenever [tilt-angle] becomes large. As shown in drawing 14 (a), in spite of using an OFF substrate by performing dry etching on the above-mentioned conditions according to this operation gestalt, the ridge 1412 with a symmetrical configuration can be formed.

[0110] The dry etching for carrying out ridge formation is stopped in the etching stopper layer 1305, as shown in drawing 13 (b). The thickness of the 2nd cladding layer 1306 of p mold AlGaInP etched by dry etching is about 1.5 micrometers. As the 2nd operation gestalt explained such a thick layer, about 1.3 micrometers is first etched by the 1st dry etching with a strong spatter component, and the about 0.2-micrometer p molds AlGaInP remaining by the 2nd dry etching with a strong chemical reaction component are etched after that. If it carries out like this, the damage by etching will not be exerted on the layer below the etching stopper layer 1305.

[0111] Moreover, as the 3rd operation gestalt explained, the 2nd cladding layer 1306 with a thickness of about 1.3 micrometers may be etched by dry etching with a strong spatter component, and the 2nd about 0.2-micrometer remaining cladding layers 1306 may be etched by wet etching as the 2nd etching.

[0112] After forming a ridge 1313, as shown in drawing 13 (c), the n mold GaAs current block layer 1309 which is n mold embedding layer is grown up alternatively, using SiO2 mask 1307 as it is.

[0113] Next, SiO2 mask 1307 is removed, and as shown in drawing 13 (d), the p mold GaAs contact layer 1310 is grown up. Finally, the p lateral electrode 1312 is formed in the rear face of the n mold GaAs substrate 1301 on the n lateral electrode 1311 and the contact layer 1310, and laser structure is completed.

[0114] In the manufacture approach of the semiconductor laser component of this operation gestalt, by setting the flow rate of halogen gas and nitrogen gas as formation of a ridge 1313 in an abbreviation 1.4 <= chlorine flow rate / nitrogen flow rate <= about 4.0 range Although the base of a ridge 1313, the side face of a ridge 1313, and the include angle theta to make use an OFF substrate while turning into about 60 - 90 degrees, they can manufacture a semiconductor laser component with a ridge configuration with sufficient symmetry. For this reason, the carrier to a barrier layer shuts up, light closes, and eye ** does not become an ununiformity, but a semiconductor laser component with high dependability with the stable transverse mode is obtained. Furthermore, according to this operation gestalt, an etching rate does not fall in spite of etching of the compound semiconductor containing aluminum. In addition, in the above explanation, in the process which carries out dry etching of the 2nd cladding layer of p mold AlGaInP, conditions are changed in the phase which etched about 1.3 micrometers of AlGaInP cladding layers by the 1st dry etching, and the 2nd dry etching is performed. Here, in order to detect easily (monitor), as it is shown in the part of this thickness of an AlGaInP cladding layer at drawing 15 (a) that the AlGaInP cladding layer with a thickness of about 1.3 micrometers was etched, the GaInP layer 1500 (thickness: about 10nm) from which the 2nd cladding layer 1506 of AlGaInP and a presentation differ may be inserted beforehand.

[0115] Since the GaInP layer 1500 does not contain aluminum when the 2nd cladding layer of AlGaInP is etched and etching advances by the GaInP layer 1500, carrying out spectrographic analysis from the plasma by forming the GaInP layer 1500, the value of spectrographic analysis changes. It is correctly detectable that about 1.3 micrometers of the 2nd cladding layer were etched with this change. And what is necessary is to perform the 2nd dry etching and just to etch that of the 2nd cladding layer of the remaining about 0.2-micrometer thickness, as etching conditions are changed and it is shown in drawing 15 (b). By carrying out like this, further, there are few damages at the time of etching, and its controllability is good, and they can manufacture the semiconductor laser component which has a uniform property.

[0116] The desorption of aluminum 2O3 can be promoted by sputtering by increasing the amount of chlorine ion generation, without the amount of chlorine radical formation making it decrease, when aluminum is contained in the sample to etch according to this operation gestalt, even if aluminum 2O3 is formed of the residual moisture in a reaction

chamber. Moreover, a chlorine radical and aluminum are made to react, and aluminum serves as an aluminum chloride and ****s. For this reason, the problem to which a sample is no longer etched into or an etching rate falls is avoidable.

[0117]

[Effect of the Invention] According to this invention, the following effectiveness is acquired.

[0118] Dry etching of the III-V group who has a smooth etching side, and an II-VI group compound semiconductor can be performed by holding about 1 or 1 or more, and internal pressure for a chlorine flow rate / nitrogen flow rate to about 1 mTorr or 1 or more mTorrs.

[0119] Moreover, dry etching of the III-V group who has a smooth etching side, and an II-VI group compound semiconductor can be performed by controlling independently the amount of a chlorine ion consistency, a chlorine radical consistency, and nitrogen ion density, and performing dry etching using the dry etching system equipped with the source of a radical, and the source of an ion beam.

[Translation done.]

TECHNICAL FIELD

[Field of the Invention] This invention relates to the dry etching approach of a compound semiconductor especially an III-V group, or an II-VI group compound semiconductor, and the semiconductor laser component produced using it.

[Translation done.]

PRIOR ART

[Description of the Prior Art] There is an approach indicated by JP,7-66175,A as a dry etching technique of the conventional compound semiconductor. By this approach, dry etching is performed to In system compound semiconductor using compound magnetic field mold ECR-RIBE (electron cyclotron resonance-reactivity ion beam etching) equipment. With compound magnetic field mold ECR-RIBE equipment, it has the coil of two functions, a main coil and a subcoil, and emission of the magnetic field near [to etch] a sample is suppressed. According to this approach, chlorine and nitrogen are used as etching gas. A perpendicular cross section and a smooth etching side are acquired [the flow rate of chlorine gas / nitrogen gas] for internal pressure to an etching mask on condition that 0.5mTorr(s) or less to one.
[0003] According to the above-mentioned official report, in chlorine gas / nitrogen gas, when supplying gas at one or less rate, generating of a chlorine radical is controlled and etching by the chlorine ion serves as dominance from a chlorine radical. For this reason, even if it uses the ion which has about teneV low energy, the balance of evaporation of the chloride of In and the chloride of P can be maintained. Consequently, etching from which a perpendicular cross section and a smooth etching side are acquired to an etching mask is realizable.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] According to this invention, the following effectiveness is acquired.
[0118] Dry etching of the III-V group who has a smooth etching side, and an II-VI group compound semiconductor can be performed by holding about 1 or 1 or more, and internal pressure for a chlorine flow rate / nitrogen flow rate to about 1 mTorr or 1 or more mTorrs.
[0119] Moreover, dry etching of the III-V group who has a smooth etching side, and an II-VI group compound semiconductor can be performed by controlling independently the amount of a chlorine ion consistency, a chlorine radical consistency, and nitrogen ion density, and performing dry etching using the dry etching system equipped with the source of a radical, and the source of an ion beam.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] Conventionally, in the dry etching of a compound semiconductor, problems, such as difficulty, had the dry area of the etching side resulting from the difference of the vapor pressure of the reactant of an III group element and etching gas and vapor pressure with the reactant of V group element and etching gas being large, and control of a cross-section configuration.
[0005] The dry etching technique indicated by above-mentioned JP,7-66175,A is also for solving this problem. With this technique, by addition of nitrogen gas, chlorine gas decomposes and the amount of generation of a chlorine radical is controlled by about 1/3 among the chlorine ion generated and the chlorine radical. The above-mentioned problem is solved by this. Moreover, with the above-mentioned technique, in order to make the amount of generation of a chlorine radical into min, the pressure in a reaction chamber is set to 0.5 or less mTorrs. Consequently, the desorption rate of the chloride of In and the chloride of P is balanced. The description of the above-mentioned technique is etching on the conditions from which chlorine radical concentration's becomes min. The above-mentioned official report does not show the quantitive data about the amount of generation and etching property of a chlorine ion.
[0006] Moreover, when aluminum is contained in the sample to etch, there is a problem to which it is no longer etched into or an etching rate falls greatly by aluminum 2O3 being formed of the residual moisture in a reaction chamber.
[0007] The place which this invention is made in view of the above-mentioned situation, and is made into the purpose As opposed to an III-V group and an II-VI group compound semiconductor, and the group III-V semiconducter that contains aluminum further Without reducing the amount of chlorine gas radical formation using the chlorine gas which added nitrogen gas It is in offering the semiconductor laser component which offered the dry etching approach by which a perpendicular cross section and a smooth etching side are acquired, and was produced using this dry etching approach, and its manufacture approach.

[Translation done.]

* NOTICES *

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1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

MEANS

[Means for Solving the Problem] The etching approach by this invention with the dry etching system equipped with the source of the plasma which generates the plasma of three or more [about 1010cm -] consistencies It is the etching approach which carries out dry etching of a group III-V semiconducter or the II-VI group compound semiconductor using the mixed gas of the gas and the nitrogen gas containing a halogen. It is (the flow rate of the gas containing a halogen) / (flow rate of nitrogen gas) about >=1, and the pressure under etching reaction is about 1 mTorr or 1 or more mTorrs, and the above-mentioned purpose is attained by that.
[0009] With a certain operation gestalt, the 1st etching process which performs the above-mentioned dry etching, and the 2nd etching process which performs wet etching are included.
[0010] With a certain operation gestalt, the ion generated in said source of the plasma is accelerated, and it etches with the kinetic energy of this accelerated ion, heating a sample front face.
[0011] With a certain operation gestalt, the ion generated in said source of the plasma is accelerated, with the kinetic energy of this accelerated ion, it heats only near the front face of the sample containing an II-VI group compound, and the susceptor of this sample is cooled.
[0012] It etches with a certain operation gestalt, heating sample susceptor.
[0013] the 1st dry etching process which accelerates with the 1st acceleration voltage and etches the ion generated in said source of the plasma with a certain operation gestalt -- this -- it carries out after the 1st dry etching process, and the ion generated in this source of the plasma is accelerated with the 2nd acceleration voltage, the 2nd dry etching process to etch is included further, and this 1st acceleration voltage is larger than this 2nd acceleration voltage.
[0014] With a certain operation gestalt, said dry etching system is equipped with the source of a radical beam, and the source of an ion beam, and it performs dry etching, controlling independently the consistency of the radical generated by this source of a radical beam, and the consistency of the ion generated by this source of an ion beam, respectively.
[0015] With a certain operation gestalt, said compound semiconductor is formed of AlxGayIn1-x-yP (0< x<=1, 0<=y<=1).
[0016] With a certain operation gestalt, said compound semiconductor is formed on the off substrate.
[0017] Other etching approaches by this invention with the dry etching system equipped with the source of the plasma which generates the plasma of three or more [about 1010cm -] consistencies It is the etching approach which carries out dry etching of a group III-V semiconducter or the II-VI group compound semiconductor using the mixed gas of the gas and the nitrogen gas containing a halogen. The 1st dry etching process which makes halogen ion density larger than a halogen radical consistency, and etches it, Halogen ion density is made smaller than a halogen radical consistency, the 2nd dry etching process to etch is included and the above-mentioned purpose is attained by that.
[0018] The etching system by this invention is equipped with the reaction chamber linked to the source of a radical beam, the source of an ion beam, and this source of a radical beam and this source of an ion beam, the sample susceptor prepared in this reaction chamber, and a load lock chamber, and the above-mentioned purpose is attained by that.
[0019] The manufacture approach of the semiconductor laser component by this invention The process which grows at least one compound semiconductor layer epitaxially on a semi-conductor substrate, The process which forms the mask by which patterning was carried out on one compound semiconductor layer even if there is none of these **, The process which etches to one compound semiconductor layer using the etching approach according to claim 1 to 10 even if this ** cannot be found, and forms a ridge stripe using this mask, The process which embeds this ridge stripe with a compound semiconductor is included, and the above-mentioned purpose is attained by that.
[0020] With a certain operation gestalt, said substrate is an inclination substrate, said at least one compound semiconductor layer contains the barrier layer, and the n mold AlGaInP cladding layer and p mold AlGaInP cladding layer which sandwich this barrier layer, and said ridge stripe contains this p mold AlGaInP layer.

[0021] With a certain operation gestalt, said p mold AlGaInP cladding layer has the 1st cladding layer of p mold AlGaInP, and the 2nd cladding layer of p mold AlGaInP, and the etching stopper layer is formed between this 1st cladding layer and this 2nd cladding layer.
[0022] With a certain operation gestalt, the layer for carrying out the monitor of the amount into which this 2nd cladding layer was etched is formed in said 2nd cladding layer of p mold AlGaInP.
[0023] The semiconductor laser component by this invention is prepared on the substrate and this substrate. A barrier layer, It is the semiconductor laser component equipped with the ridge stripe containing n mold cladding layer which sandwiches this barrier layer, and p mold cladding layer. This ridge stripe It has the laser section which carries out laser oscillation, and a point, the base of this ridge stripe, the side face of this ridge stripe, and the include angle to make are about 60 degrees or more 90 degrees or less, and the above-mentioned purpose is attained by that.
[0024] With a certain operation gestalt, said point has the width of face which becomes thin in the shape of a taper from the width of face of said laser section, and this width of face is about 1 micrometer or less.
[0025] With a certain operation gestalt, said point has the width of face which becomes larger to the shape of a taper than the width of face of said laser section.
[0026] Other semiconductor laser components by this invention are semiconductor laser components equipped with the inclination substrate, and the n mold AlGaInP cladding layer formed on this substrate, a barrier layer and a p mold AlGaInP cladding layer, this p mold AlGaInP cladding layer has ridge structure with an almost symmetrical configuration, the current block layer is formed in the both sides of this ridge structure, and the above-mentioned purpose is attained by that.
[0027] With a certain operation gestalt, said p mold AlGaInP cladding layer has the 1st cladding layer of p mold AlGaInP, and the 2nd cladding layer of p mold AlGaInP, and the etching stopper layer is formed between this 1st cladding layer and this 2nd cladding layer.
[0028] With a certain operation gestalt, the layer for carrying out the monitor of the amount into which this 2nd cladding layer was etched is formed in said 2nd cladding layer of p mold AlGaInP.
[0029]
[Embodiment of the Invention] Below, the operation gestalt of this invention is explained at a detail.
[0030] (1st operation gestalt) As 1st operation gestalt of the dry etching approach by this invention, the dry etching approach for a group III-V semiconducter is explained. InP is used as a sample to etch. Chlorine gas and nitrogen gas are used as etching gas. Drawing 1 shows the configuration of the ECR-RIBE equipment (it is called ECR-RIBE equipment for short electron cyclotron resonance-reactivity ion beam etching and the following) used with this operation gestalt in ** type. In this equipment, the location of the sample to etch is located on the outside of the coil which generates a magnetic field.
[0031] As shown in drawing 1, ECR-RIBE equipment is connected with ECR source 101 and the ECR source, and is mainly equipped with the reaction chamber 102 and exhaust air pump system (not shown) for installing a sample. Ion and a radical are generated in ECR source 101. From a gas inlet 108, the chlorine gas and the nitrogen gas by which the flow rate was controlled are introduced into ECR source 101. Furthermore, 2.45GHz microwave will face the quartz aperture 107, and will be introduced into ECR source 101, and chlorine gas and nitrogen gas will be from a waveguide 106 in an excitation state. An electron sympathizes with the 875 gauss magnetic field generated with the coil 103, and it repeats gas and a collision, carrying out the circular motion. In this way, it is accelerated by the grid 104 and the chlorine ion and nitrogen ion which were generated in ECR source 101 are irradiated by the sample 105.
[0032] Although it is accelerated and a chlorine ion and nitrogen ion are irradiated by the sample 105, since it is not ionized, the chlorine radical and nitrogen radical which are generated in ECR source 101 are not accelerated. However, a chlorine radical and a nitrogen radical arrive at the front face of a sample 105 by diffusion, and contribute to etching. As for this ECR-RIBE equipment, unlike the compound magnetic field mold, the coil is not installed in the side face of a reaction chamber 102. For this reason, the magnetic field generated with a coil 103 is an emission magnetic field.
[0033] The ion and radical which were produced as mentioned above arrive at sample 105 front face, react with InP which is a sample, and In chloride and P chloride generate them. The boiling point of PCl_3 has the boiling point of 76 degrees C and PCl_5 as low as 162 degrees C, and evaporates P chloride easily.
[0034] On the other hand, the boiling point of 560 degrees C and $InCl_3$ has the boiling point of 608 degrees C and $InCl_2$ as high as 600 degrees C, and the boiling point of InCl cannot evaporate In chloride easily. For this reason, the layer of In chloride is formed in the front face of a sample 105. Since evaporation of In chloride is promoted, the acceleration voltage of ion serves as an important element, because the chlorine ion and nitrogen ion which were accelerated collide with the front face of a sample 105 from ECR source 101. Less than [acceleration voltage 300V], evaporation does not take place and In chloride is not etched.

[0035] Table 1 shows the conditions of etching of being used with this operation gestalt.
[0036]
[Table 1]

塩素	窒素	マイクロ波パワー	加速電圧	内圧	試料温度
3~20 SCCM	3.5~35 SCCM	200W(固定)	300~900 V	0.5~2.5 mTorr	室温 -300℃

[0037] In the conditions shown in Table 1, acceleration voltage is about 300v or more, and etching is the optimal. In addition, SiO2 is used as a mask for etching.
[0038] The main results of having performed dry etching to below using the conditions shown in Table 1 are explained.
[0039] In the experiment, the chlorine flow rate was set as about 10 SCCM(s), about 2.5 mTorr(s) and sample temperature were set [acceleration voltage] as about 200 degrees C for the internal pressure under about 650V and reaction, the nitrogen flow rate was changed, and dry etching was performed. Evaporation of an III group compound can be promoted by heating sample susceptor and maintaining sample temperature at about 200 degrees C.
[0040] As a nitrogen flow rate, drawing 2 shows each cross-section photograph of InP to which about 35 SCCM(s) and drawing 3 performed about 7 SCCM(s) on condition that about 3.5 SCCM(s), and drawing 4 performed dry etching in a mimetic diagram.
[0041] Drawing 2 (a) shows the cross section etched using SiO2 mask to an InP substrate. Although InP is etched as shown in this drawing, the base (etching side) is very ruined. Drawing 2 (b) is the perspective view of drawing 2 (a). Drawing 2 (b) also shows well that the base is ruined. In the case of drawing 3 , etching is possible in the almost perpendicular direction to SiO2 mask, and most base dry areas are lost. In the case of drawing 4 , there is no base dry area and the etching side is smooth. However, side etching into which the mask bottom is also etched takes place, and perpendicular etching has not been performed to the mask.
[0042] The above-mentioned result shows that there is a boundary where the etching side of nitrogen flow rate [a chlorine flow rate /] is ruined between about 0.29 and 1.43. According to the experiment, it turned out that the ratios of the chlorine flow rate / nitrogen flow rate of the boundary are the about 1.0 neighborhoods. Moreover, it turns out that the smooth nature of an etching side has [the about 2.85 neighborhoods] the best ratio of a chlorine flow rate / nitrogen flow rate.
[0043] However, if the cross-section configuration of drawing 4 is seen, it is not perpendicular and side etching is considerably contained. In order to obtain a perpendicular cross section, it is necessary to stop the chemical reaction component in dry etching. Then, it etched by lowering sample temperature to about 100 degrees C. The result is shown in drawing 5 (conditions other than temperature are the same as the case of drawing 4).
[0044] By lowering sample temperature to 100 degrees C, a spatter component will become strong from chemical reactivity, and SiO2 mask will retreat by being etched (it moves to a substrate side). For this reason, over etching happens and it becomes a trapezoid cross-section configuration. However, since the etching side is very smooth, it is satisfactory practically also in a trapezoid cross section.
[0045] As shown in drawing 4 and 5, when the chemical reaction component in etching is more superior than a spatter component, side etch happens, when a spatter component is more superior than chemical reactivity, a mask retreats and over-etching happens.
[0046] Next, examination of the etching conditions for obtaining a perpendicular cross section is explained.
[0047] In order to make chemical reactivity increase, sample temperature was made into about 150 degrees C, in order to raise an etching rate, the amount of supply of chlorine was increased up to about 11.5 SCCM(s) (a nitrogen flow rate is 3.5SCCM(s) as well as the case of drawing 4), and it etched. The result is shown in drawing 6 . A spatter component and a chemical reaction component can be balanced and a perpendicular etching cross section is realized so that drawing 6 may show. In this case, acceleration voltage is about 650V and internal pressure is still about 2.5 mTorr(s).
[0048] Each etching condition in drawing 2 -6 is collectively shown in Table 2.
[0049]
[Table 2]

	塩素 (SCCM)	窒素 (SCCM)	塩素／窒素 流量比	加速電圧 (V)	内圧 (mTorr)	試料温度 (℃)
図2	10	35	0.29	650	2.5	200
図3	10	7	1.43	650	2.5	200
図4	10	3.5	2.8	650	2.5	200
図5	10	3.5	2.8	650	2.5	100
図6	11.5	3.5	3.29	650	2.5	150

[0050] It will not be ruined if the ratio of a chlorine flow rate / nitrogen flow rate is about 1.0 or more. However, if this flow rate is made large to 6.4 or more, it will begin to be ruined for a while again. In consideration of the dry area of an etching side, the range of the optimum value of the flow rate of a chlorine flow rate / nitrogen flow rate is about 1.0 to 6.4.
[0051] drawing 16 -- the spectrum of plasma luminescence -- a result is shown. An optical result expresses a change of the nitrogen ion and chlorine ion to nitrogen concentration, and a chlorine radical on the strength at this rate. Each luminescence reinforcement shown in drawing 16 is standardized by the plasma luminescence reinforcement of only chlorine gas. As for nitrogen ion, 652.9nm was observed, and, as for the chlorine ion, luminescence by 727.9nm was observed, as for 450.8nm and a chlorine radical. Luminescence by 652.9nm only in the case of chlorine gas is a noise, and is not luminescence by nitrogen ion.
[0052] The luminescence reinforcement of nitrogen ion increases simply in proportion to the addition of nitrogen. Although the luminescence reinforcement by the chlorine ion increases by addition of nitrogen, the addition concentration of nitrogen shows maximum at about 23%. This maximum is about 1.4 times in nitrogen additive-free. Then, according to the increment in nitrogen addition concentration, slight luminescence reinforcement by the chlorine ion decreases, and is saturated with one about 1.3 times [in nitrogen additive-free] the value of this. although it increases about 10% by addition of nitrogen, it comes out to this extent and the luminescence reinforcement by the chlorine radical is saturated, and even if it adds nitrogen further, it does not increase.
[0053] Below, change of the above-mentioned luminescence reinforcement is explained as compared with an etching property.
[0054] When a chlorine flow rate / nitrogen flow rate is less than one, the nitrogen concentration in drawing 16 is a field (field **) exceeding 50%. In field **, although chlorine ion reinforcement is about 1.3 or more times to the case of pure chlorine (nitrogen additive-free), nitrogen ionic strength has increased about 3 times. That is, it is thought with superfluous nitrogen ion by carrying out the spatter of the P chloride with vapor pressure high among In chloride and P chloride alternatively that it is ruined.
[0055] When a chlorine flow rate / nitrogen flow rate is 6.4 or less [about 1 or more], the nitrogen concentration of drawing 16 is equivalent to about 50% or less of field (field **) about 13% or more. In this field, the reinforcement of nitrogen ion does not increase so much, but balance of the desorption from the front face of In chloride and P chloride can be taken, and the smooth etching side is realized.
[0056] When a chlorine flow rate / nitrogen flow rate exceeds 6.4, the nitrogen concentration of drawing 16 is equivalent to about 13% or less of field (field **). In field **, it is ruined again. Since the desorption of In chloride which this generated, and P chloride mainly happens with heat energy from the spatter effectiveness, it is thought that it is because the alternative desorption of P chloride happens.
[0057] As stated above, the effectiveness which adds nitrogen gas not only promotes generation of a chlorine ion, but in this invention, the big description has it in the place which promotes the desorption of the chloride of an III group or V group according to the spatter effectiveness by the nitrogen ion itself. This is also the same as when this invention is applied to an II-VI group compound semiconductor.
[0058] In the above explanation, as an ingredient to etch, although a group's III-V semiconducter InP was used, the ingredient of an AlGaInP system, an AlGaInN system, and the ZnMgSSe system of an II-VI group compound semiconductor may be used instead of InP so that it may explain later. Moreover, although an etching rate falls, etching is possible even if it holds substrate temperature to a room temperature.
[0059] (2nd operation gestalt) Below, the dry etching approach for a group III-V semiconducter is explained as 2nd operation gestalt of the dry etching approach by this invention. More specifically, the dry etching approach to etch is explained with the kinetic energy of the accelerated ion, heating only a sample front face, without raising the temperature of the whole sample.

[0060] InP is used as an etching sample and SiO2 is used as an etching mask. In addition, the approach of this operation gestalt is applicable to etching of an II-VI group compound semiconductor.

[0061] As the operation gestalt of the above 1st described, when raising sample temperature, the chemical reaction component in dry etching becomes dominance from a spatter component, and side etching into which the mask bottom is also etched takes place. However, if sample temperature is lowered, since a spatter component will become strong, over-etching to which a mask retreats is caused, or an etching base is ruined.

[0062] So, with this operation gestalt, it is made to stick to the sample maintenance fixture which produced the sample with aluminum, and it etches, cooling this maintenance fixture.

[0063] By the grid, it is accelerated by hundreds V and the ion generated in an ECR source is irradiated by the sample with kinetic energy. The radical generated in an ECR source is not accelerated. Since the energy per radical has many radicals generated with 20-30eV although it is small, the total energy received from a radical has a quite large sample front face. Thus, in order that a sample front face may obtain many ion and the energy of a radical, even if it does not go up the temperature of a sample substrate, the same effectiveness as the case where the sample itself is raised to hundreds of degrees C is acquired. That is, by heating the front face of a sample in this way, evaporation of the chloride of an III group or II group is promoted, and an etching rate is improved.

[0064] ECR-RIBE equipment is used, about 200W and internal pressure are set to about 2.5 mTorr(s), it sets [a chlorine flow rate / about 11.5 SCCM(s) and a nitrogen flow rate] acceleration voltage to about 650 V for about 3.5 SCCM(s) and microwave power, and drawing 8 shows the cross section of InP at the time of performing dry etching to InP.

[0065] In this case, it is not heating to the whole sample. The sample maintenance fixture produced with aluminum is equipped with the sample. A sample maintenance fixture is put on the sample susceptor by which water cooling was carried out. Only the part near the front face of a sample is heated by this, and the temperature of the part except this part does not rise by it. A sample is protected from a thermal damage. Especially the thing done like this is effective in etching the sample containing an II-VI group compound. Because, since the crystal growth temperature (about 260 degrees C) of an II-VI group compound semiconductor is low, in order to prevent crystalline degradation, it is necessary to make etching temperature lower (about 250 degrees C or less) than crystal growth temperature.

[0066] As the operation gestalt of the above 1st described, the configuration of an etching cross section reflects the balance of the spatter component to etch and a chemical reaction component. That is, when a spatter component is dominance, over-etching of the cross section is carried out, and when a chemical reaction component is dominance, side etching takes place.

[0067] Although the temperature of the whole sample is near a room temperature according to this operation gestalt as drawing 8 shows, the cross section is almost perpendicular and has balanced the chemical reaction component and the spatter component. The cross section of drawing 8 shows the same cross-section configuration as the case of drawing 6 , when it etches by setting sample temperature as 150 degrees C. That is, the result shown in drawing 8 which etched without heating is the same as the result shown in drawing 6 which etched by setting sample temperature as 150 degrees C about the cross-section configuration. However, the etching rate in the case of drawing 8 is lower than it in the case of drawing 6 25%.

[0068] In addition, with this operation gestalt, although sample temperature is set up near the room temperature, it can also make the difference [chloride / of an III group] of sublimation small by cooling sample susceptor at 0 degree C or less, and controlling sublimation of V group's chloride. This can perform dry etching from which a perpendicular cross section and a smooth etching side are acquired.

[0069] (3rd operation gestalt) As 3rd operation gestalt of the dry etching approach by this invention, the dry etching approach for a group III-V semiconducter is explained. The dry etching approach of more specifically performing two steps of etching of different conditions is explained. As a sample, SiO2 is used as InP and an etching mask, and chlorine and nitrogen are used as etching gas.

[0070] The 1st dry etching is first performed using ECR-RIBE equipment. In this 1st dry etching, by setting internal pressure to about 1 or less mTorr, and setting acceleration voltage to about 300v or more, the collision between gas molecules is suppressed and ion density is made larger than a radical consistency. About 1 or more and sample temperature are set as about 100 degrees C for a chlorine flow rate / nitrogen flow rate. In this case, etching by the spatter component becomes dominance from a chemical reaction component, the high-speed dry etching in a perpendicular direction progresses to a sample front face, and the configuration near a desired configuration is formed.

[0071] The 1st dry etching of the above has the above and a comparatively high etching rate by about 1000A/. When etching at high speed, in the etched side face or etching side, the damage by which induction is carried out to processing arises, or it is ruined. This is because a crystal defect arises in a sample, when it is accelerated on the high electrical potential difference beyond 300V and the halogen ion generated in an ECR source is irradiated by the sample. Moreover,

since the boiling points of a halogenide differ to an III group (or II group) and V groups (or VI group), when the stoichiometry in an etching side shifts, it is because the III group (or II group) elements in an etching side increase in number more than V group (or VI group) element in an excess.
[0072] Next, it continues at the 1st dry etching and the 2nd dry etching is performed. It is removing the layer which has the processing induction damage produced by the 1st dry etching as a purpose which performs this 2nd dry etching. Moreover, it is removing the devastated field and making it smooth by the 1st dry etching, when a dry area's arises in an etching side. In order to attain the above-mentioned purpose, about 3 or more and internal pressure are set as about 2 or more mTorrs, it sets about 300v or less and sample temperature as about 200 degrees C for acceleration voltage, and the 2nd dry etching performs a chlorine flow rate / nitrogen flow rate. In this case, the collision between gas molecules increases and the radical consistency becomes large from ion density. Furthermore, since a mean free path becomes small, the chemical reaction component acts strongly from a spatter component.
[0073] Since the processing induction damage done to a crystal is small, etching under the strong conditions of the above chemical reactivity can remove a layer including many processing induction damages produced in the 1st dry etching. When ruined in the 1st dry etching, the devastated field can be made smoother by the 2nd dry etching of the above.
[0074] The 1st dry etching is a chlorine flow rate. Although it can carry out on condition that /nitrogen flow rate abbreviation >=1, internal pressure abbreviation <=1mTorr, and acceleration voltage abbreviation >=300V, a chlorine flow rate / nitrogen flow rate abbreviation >=3, internal pressure abbreviation <=0.5mTorr, and acceleration voltage abbreviation >=600V are more more desirable as optimum conditions.
[0075] Although the 2nd dry etching can be performed on condition that a chlorine flow rate / nitrogen flow rate abbreviation >=3, internal pressure abbreviation >=2mTorr, and acceleration voltage abbreviation <=300V, a chlorine flow rate / nitrogen flow rate abbreviation >=10, internal pressure abbreviation >=3mTorr, and acceleration voltage abbreviation <=100V are more more desirable as optimum conditions.
[0076] Drawing 12 is the sectional view showing the process of the dry etching by this operation gestalt. First, as shown in drawing 12 (a), SiO2 mask 1202 by which patterning was carried out is formed on the InP substrate 1201. Then, as shown in drawing 12 (b), the 1st dry etching is performed. According to this process, the damage layer 1203 by which induction is carried out to processing arises on an etching front face. Next, as shown in drawing 12 (c), the 2nd dry etching is performed. In the 2nd dry etching, a chlorine ion consistency is small and a chlorine radical consistency is larger than the case of the 1st dry etching. By performing the 2nd dry etching, the damage layer 1203 by which induction is carried out to processing is removed, and a perpendicular side face and a smooth etching side can be formed to a mask 1202.
[0077] In addition, in the above explanation, the size relation of the chlorine ion consistency and chlorine radical consistency in the 1st and 2nd dry etching was changed by changing internal pressure, flow rate, and acceleration voltage. Instead, the 1st and the 2nd dry etching may be performed by changing only acceleration voltage. That is, the 1st and 2nd dry etching is a chlorine flow rate. Using conditions with /nitrogen flow rate abbreviation >=3, an internal pressure abbreviation >=2mTorr, and a sample temperature of about 200 degrees C, in the 1st dry etching, acceleration voltage is set as about 900V, and acceleration voltage is set as about 100 V by the 2nd dry etching. On such conditions, even if it performs dry etching, etching without a dry area is realizable.
[0078] (4th operation gestalt) Below, the etching approach for a group III-V semiconducter is explained as 4th operation gestalt of the etching approach by this invention. More specifically, the etching approach of performing two steps of etching, dry etching and wet etching, is explained. As a sample, SiO2 is used as InP and an etching mask, and chlorine and nitrogen are used as etching gas. As an etching solution of wet etching, a hydrochloric acid, an acetic acid, and hydrogen peroxide solution are used.
[0079] First, 1st etching (dry etching) is performed using ECR-RIBE equipment. In this 1st etching, abbreviation >=1 and internal pressure are made to about 2 or more mTorrs, and about 300v or more and sample temperature are made [a chlorine flow rate / nitrogen flow rate] into about 100 degrees C or more for acceleration voltage. Although the 1st etching is possible on the above-mentioned conditions, for about 3.5 SCCM(s) and sample temperature, about 150 degrees C and acceleration voltage are [a chlorine flow rate / about 11.5 SCCM(s) and a nitrogen flow rate / about 650V and internal pressure of optimum conditions] about 2.5 mTorr(s). On such conditions, a sample is processible into a predetermined configuration. A layer including the processing induction damage generated by the 1st etching is removed by the 2nd etching explained below.
[0080] Drawing 7 shows typically the configuration of the spin etching system used for the 2nd etching. 2nd etching, i.e., wet etching, is performed in a reaction chamber 705. The sample 701 by which dry etching was carried out [above-mentioned] is installed on the sample maintenance base 702. The sample maintenance base 702 holds a sample 701 by the vacuum chuck, and rotates with a predetermined rotational speed. The mixed liquor of the hydrochloric acid which is

maintained by the etchant tank 704 and saved to predetermined temperature at it, an acetic acid, and hydrogen peroxide solution comes out of a nozzle 703, and flows and falls on a sample 701. The core of a nozzle 703 and the sample maintenance base 702 is in agreement, and a nozzle 703 reciprocates the between to a predetermined distance to radial [of the core of the sample maintenance base 702 to a sample maintenance base]. While a nozzle 703 fails to flow liquid in the sample 701 to rotate, very uniform wet etching is performed by reciprocating radial. In this way, the damage layer by which induction is carried out to processing produced by the 1st etching is removed. The temperature of 3:36:1 and mixed liquor of the mixing ratio of a hydrochloric acid, an acetic acid, and hydrogen peroxide solution should just be 20 degrees C.

[0081] Since wet etching does not contain a spatter component, some damages which are given by using dry etching can also be prevented by using wet etching. For this reason, the smooth nature of an etching side can be improved further.

[0082] In this operation gestalt, as a solution used for the 2nd etching, although a hydrochloric acid, an acetic acid, and hydrogen peroxide solution were used, it may replace with this and the mixed liquor of the mixed liquor of the mixed liquor of a sulfuric acid, hydrogen peroxide solution, and water, a hydrochloric acid, and a phosphoric acid or saturation bromine water, and a methanol may be used. What is necessary is just the solution from which induction is carried out to processing produced by the 1st etching in short, and a damage layer can be removed.

[0083] (5th operation gestalt) The dry etching system which equipped below with the source of a radical beam and the source of an ion beam other than an ECR source, and the dry etching approach using it are explained.

[0084] Drawing 9 shows typically the configuration of the dry etching system of this operation gestalt. This equipment is equipped with the source 902 of a radical beam and the source 903 of an ion beam other than ECR source 904 and a reaction chamber 901. The source 902 of a radical beam and the source 903 of an ion beam are connected to the reaction chamber 901.

[0085] All over the reaction chamber 901, it has the sample maintenance base 905 holding a sample 906. The chlorine ion generated by the chlorine radical generated in the source 902 of a radical beam, the chlorine ion generated in the source 903 of an ion beam, and ECR source 904, a chlorine radical, and nitrogen ion are irradiated by the sample 906. A sample 906 is sent to a reaction chamber 901 from the load lock chamber 900 for paying a sample 906 to a reaction chamber 901. A reaction chamber 901 is exhausted by about 10 to 6 or less Torrs by the exhaust air system (not shown).

[0086] In the source 902 of a radical beam, RF RF will be added and chlorine gas will be in the plasma state. A chlorine ion and a chlorine radical occur by this. Since a mean free path is several centimeters, it collides with other atoms or an electron and a chlorine ion disappears in the source 902 of a radical, or a reaction chamber 901 when not accelerated, it does not reach to a sample. The generated radical arrives even at a sample front face by diffusion, and contributes to a reaction.

[0087] On the other hand, also in the source 903 of an ion beam, RF RF will be added and chlorine gas will be in the plasma state. A chlorine ion and a chlorine radical occur by this. By changing the electrical potential difference applied to the drawer electrode 9031, by changing the rate of the chlorine ion pulled out from the source 903 of an ion beam, and a chlorine radical, many chlorine ions are pulled out and irradiated on a sample front face from a chlorine radical.

[0088] In ECR source 904, as the 1st operation gestalt described, gas is decomposed and ion and a radical are generated. Nitrogen gas is introduced into ECR source 904 in this operation gestalt.

[0089] The consistency of the radical which contributes to the smooth nature of the gas which contributes to a reaction, and the consistency of the ion contributed to an etching rate are independently controllable, respectively by having the ion source, a source of a radical, and an ECR source as mentioned above. For this reason, high-speed etching is possible, with the smooth nature of an etching side maintained. It becomes easy to control the smooth nature of an etching rate, a cross-section configuration, and an etching side. As the 1st operation gestalt described in the case of the dry etching of InP by the mixed gas of chlorine and nitrogen, using SiO2 as a mask, P chloride is sublimated easily, and since it is hard to sublimate In chloride, the layer of In chloride will be formed in a sample front face. What is necessary is just to use the kinetic energy of the accelerated chlorine ion and nitrogen ion, in order to make the layer of this In chloride sublimate.

[0090] Then, what is necessary is to make [more] a chlorine ion flow rate than a chlorine radical flow rate, to accelerate by the high voltage of about 300v or more, and just to supply a chlorine ion and nitrogen ion. What is necessary is just to set sample temperature as about 150 degrees C or more, in order to make an etching rate high.

[0091] According to this operation gestalt, the dry etching of InP in which about 300v or more and the nitrogen ion from an ECR source are [about 10 or more SCCMs and acceleration voltage] about 3 or less SCCMs for the chlorine ion flow rate from about 1 or more SCCMs and the source of an ion beam, and the chlorine radical flow rate from the source of a radical beam has a smooth etching side is possible. Furthermore, dry etching in which a chlorine radical flow rate has the cross section about 1 SCCM and a chlorine ion flow rate has [the acceleration voltage of about 10 SCCM(s) and a chlorine ion / about 600v or more and the nitrogen flow rate of an ECR source] about 3 SCCM(s) and sample

temperature perpendicular in a cross section on the conditions which are about 150 degrees C, and a smooth etching side is realized.

[0092] (6th operation gestalt) Below, the manufacture approach of a semiconductor laser component is explained using the etching approach explained with the operation gestalt of the above 1-5ths. The diameter conversion laser of a spot is used as a semiconductor laser component. Drawing 10 (a) - (c) shows typically the cross section of the structure of the diameter conversion laser of a spot.

[0093] This diameter conversion laser of a spot has the laser section 1010 and the spot-size transducer (point) 1011, as shown in drawing 10 (a). The laser section 1010 has the stripe configuration which has fixed width of face and thickness. As for the spot-size transducer 1011, width of face is [width of face] small toward the outgoing radiation edge 1012 at the shape of a taper. A laser beam is changed into the path m of the outgoing radiation edge (tip of a point 1011) 1012 of the spot-size transducer 1011 from the diameter of a spot in the laser section 1010, while guiding the spot-size transducer 1011. Width of face m is [the include angle of about 1 micrometer or less (typically about 0.6 micrometers) and a cross section of the outgoing radiation edge 1012] about 90 degrees.

[0094] Drawing 10 (b) shows the cross section in alignment with line A-A' of drawing 10 (a). As shown in drawing 10 (b), epitaxial growth of the n-InP layer 1002, the n-InGaAsP cladding layer 1003, a barrier layer 1004, the p-InGaAsP cladding layer 1005, and the p-InP cap layer 1007 is carried out one by one on the n-InP substrate 1001. these layers -- the mesa stripe (ridge stripe) 1014 -- constituting -- the mesa stripe 1014 -- half--- it is embedded by insulating InP1006. The p lateral electrode 1009 is formed on the p-InP cap layer 1007, and the n lateral electrode 1008 is formed all over the rear face of a substrate 1001.

[0095] The electron hole poured in from the p lateral electrode 1009 is recombined by the electron and barrier layer 1004 which were poured in from the n lateral electrode 1008. Luminescence takes place under the p lateral electrode 1009, and carries out laser oscillation by being shut up in a resonator end face.

[0096] Drawing 10 (c) shows the cross section in alignment with line B-B' of drawing 10 (a). The laser section 1010 differs in the width of face of a barrier layer 1004 from the spot-size transducer 1011 so that drawing 10 (b) and drawing 10 (c) may be compared and understood. That is, the direction of the width of face of the barrier layer 1004 of the spot-size transducer 1011 is small.

[0097] Below, the manufacture approach of the diameter conversion laser of a spot is shown, referring to drawing 11 (a) - (g). Drawing 11 (a) - (g) is the mimetic diagram of the cross section of the laser section 1010. The width of face of a barrier layer etc. only differs, and the spot-size transducer 1011 is manufactured by the laser section 1010 and coincidence.

[0098] First, as shown in drawing 11 (a), sequential growth of the n-InP layer 1102, the n-InGaAsP cladding layer 1103, a barrier layer 1104, and the p-InGaAsP cladding layer 1105 is carried out on the n-InP substrate 1101 by metal-organic chemical vapor deposition (MOVPE law). Then, as shown in drawing 11 (b), SiO2 mask 1106 which has a predetermined configuration is formed on the p-InGaAsP cladding layer 1105.

[0099] Next, as shown in drawing 11 (c), the mesa stripe (ridge stripe) 1109 is formed using ECR-RIBE equipment by the etching approach explained with the operation gestalt of the above 1-5ths. Chlorine flow rate / nitrogen flow rate abbreviation >=1, and microwave power about 200W, the internal pressure of about 2 or more mTorrs, the sample temperature of about 150 degrees C or more, and the acceleration voltage of the conditions of etching are about 300v or more. The side face of a mesa stripe and the front face of a substrate 1101 which are formed on this condition, and the include angle theta to make are about 60 degrees or more 90 degrees or less, as shown in drawing 11 (c) and (g). next, it is shown in drawing 11 (d) -- as -- MOVPE -- law -- SiO2 mask 1106 -- as the mask of selective growth -- using -- crystal growth -- carrying out -- the mesa stripe 1109 -- half--- it embeds by insulating InP1107. after removing SiO2 mask 1106, it is shown in drawing 11 (e) -- as -- MOVPE -- the p-InGaAsP cap layer 1108 is grown up by law. Finally, as shown in drawing 11 (f), it heat-treats by vapor-depositing the p lateral electrode 1111 and the n lateral electrode 1110, and ohmic contact is formed.

[0100] As explained above, according to this invention, a cavity and waveguide with the front face of the substrate 1101 as shown in drawing 11 (g), the side attachment wall of the mesa stripe whose include angle theta to make is about 60 degrees - 90 degrees, and outgoing radiation opening of 1 micrometer or less of **** can be formed by etching with ECR-RIBE equipment using chlorine gas and nitrogen gas. According to the approach of this invention, it is avoidable that the reverse mesa (the above-mentioned include angle theta is 90 degrees or more) to which the dependability of a component is fallen is formed.

[0101] In addition, in the above-mentioned explanation, although the width of face of a point 1011 is narrower to the shape of a taper than the width of face of the laser section 1010, it may become larger to the shape of a taper than the width of face of the laser section 1010.

[0102] In the above operation gestalt, although ECR-RIBE equipment was used, it may replace with this and the dry etching system equipped with the source of the inductive-coupling mold plasma, the dry etching system equipped with the source of the Helicon mold plasma, or the dry etching system equipped with the source of the NLD mold plasma may be used.

[0103] Moreover, although the above operation gestalt explained using InP as a compound semiconductor, other III-V groups or II-VI group compound semiconductors may be used. In addition, in the above explanation, although chlorine gas was used, the gas containing chlorine, a bromine, or iodine may be used.

[0104] (7th operation gestalt) Below, the manufacture approach of other semiconductor laser components is explained using the etching approach explained with the operation gestalt of the above 1-5ths, referring to drawing 13 (a) - (d). In this operation gestalt, the compound semiconductor etched contains aluminum (aluminum).

[0105] first, it is shown in drawing 13 (a) -- as -- MOVPE -- on the n mold GaAs substrate 1301 by law A n mold GaAs buffer layer (un-illustrating), n mold AlxGayIn1-x-yP (0< x<=1, 0<=y<=1, and the following) AlGaInP The cladding layer 1302 called for short, the multiplex quantum well barrier layer 1303 constituted by an AlGaInP barrier layer and the GaInP well layer, the 1st cladding layer 1304 of p mold AlGaInP, the GaInP etching stopper layer 1305 (thickness: about 5nm), Epitaxial growth of the 2nd cladding layer 1306 of p mold AlGaInP is carried out. The GaAs substrate 1301 is an off substrate which inclines in the [110] directions about 10 degrees from the field (100).

[0106] Next, in order to form a ridge, 4 micrometers of **** and SiO2 mask 1307 with a thickness of about 0.5 micrometers by which patterning was carried out are formed on the p mold AlGaInP layer 1306.

[0107] Next, as shown in drawing 13 (b), a ridge 1313 is formed by using SiO2 mask 1307 as an etching mask using the dry etching approach explained by the above 1-5ths. As conditions for etching, a chlorine flow rate / nitrogen flow rate is set as about 3.1 by setting a chlorine flow rate to about 11 SCCM(s), and setting nitrogen to about 3.5 SCCM(s). In addition, acceleration voltage is [about 2.5 mTorr(s) and the sample temperature of about 650V and internal pressure] about 100 degrees C. The ridge 1313 of symmetrical trapezoidal shape is obtained by performing dry etching on such conditions.

[0108] Usually, by etching using an inclination substrate, as shown in drawing 14 (b), a ridge does not become the configuration of bilateral symmetry. Since the substrate inclines from a field (100), in the wet etching using the etching reagent of a sulfuric-acid system, the inclination of the side face in the pars basilaris ossis occipitalis of a ridge becomes loose, and a ridge serves as an unsymmetrical configuration. Consequently, impregnation of the carrier to a barrier layer and light close, eye ** becomes an ununiformity, and the transverse mode becomes unstable. This becomes remarkable when operating laser at an elevated temperature especially.

[0109] Moreover, in the semiconductor laser of an AlGaInP system, in order to short-wavelength-ize wavelength of a laser beam, whenever [tilt-angle] is enlarged increasingly. The asymmetry of a ridge becomes larger as whenever [tilt-angle] becomes large. As shown in drawing 14 (a), in spite of using an OFF substrate by performing dry etching on the above-mentioned conditions according to this operation gestalt, the ridge 1412 with a symmetrical configuration can be formed.

[0110] The dry etching for carrying out ridge formation is stopped in the etching stopper layer 1305, as shown in drawing 13 (b). The thickness of the 2nd cladding layer 1306 of p mold AlGaInP etched by dry etching is about 1.5 micrometers. As the 2nd operation gestalt explained such a thick layer, about 1.3 micrometers is first etched by the 1st dry etching with a strong spatter component, and the about 0.2-micrometer p molds AlGaInP remaining by the 2nd dry etching with a strong chemical reaction component are etched after that. If it carries out like this, the damage by etching will not be exerted on the layer below the etching stopper layer 1305.

[0111] Moreover, as the 3rd operation gestalt explained, the 2nd cladding layer 1306 with a thickness of about 1.3 micrometers may be etched by dry etching with a strong spatter component, and the 2nd about 0.2-micrometer remaining cladding layers 1306 may be etched by wet etching as the 2nd etching.

[0112] After forming a ridge 1313, as shown in drawing 13 (c), the n mold GaAs current block layer 1309 which is n mold embedding layer is grown up alternatively, using SiO2 mask 1307 as it is.

[0113] Next, SiO2 mask 1307 is removed, and as shown in drawing 13 (d), the p mold GaAs contact layer 1310 is grown up. Finally, the p lateral electrode 1312 is formed in the rear face of the n mold GaAs substrate 1301 on the n lateral electrode 1311 and the contact layer 1310, and laser structure is completed.

[0114] In the manufacture approach of the semiconductor laser component of this operation gestalt, by setting the flow rate of halogen gas and nitrogen gas as formation of a ridge 1313 in an abbreviation 1.4 <= chlorine flow rate / nitrogen flow rate <= about 4.0 range Although the base of a ridge 1313, the side face of a ridge 1313, and the include angle theta to make use an OFF substrate while turning into about 60 - 90 degrees, they can manufacture a semiconductor laser component with a ridge configuration with sufficient symmetry. For this reason, the carrier to a barrier layer shuts up,

light closes, and eye ** does not become an ununiformity, but a semiconductor laser component with high dependability with the stable transverse mode is obtained. Furthermore, according to this operation gestalt, an etching rate does not fall in spite of etching of the compound semiconductor containing aluminum. In addition, in the above explanation, in the process which carries out dry etching of the 2nd cladding layer of p mold AlGaInP, conditions are changed in the phase which etched about 1.3 micrometers of AlGaInP cladding layers by the 1st dry etching, and the 2nd dry etching is performed. Here, in order to detect easily (monitor), as it is shown in the part of this thickness of an AlGaInP cladding layer at drawing 15 (a) that the AlGaInP cladding layer with a thickness of about 1.3 micrometers was etched, the GaInP layer 1500 (thickness: about 10nm) from which the 2nd cladding layer 1506 of AlGaInP and a presentation differ may be inserted beforehand.

[0115] Since the GaInP layer 1500 does not contain aluminum when the 2nd cladding layer of AlGaInP is etched and etching advances by the GaInP layer 1500, carrying out spectrographic analysis from the plasma by forming the GaInP layer 1500, the value of spectrographic analysis changes. It is correctly detectable that about 1.3 micrometers of the 2nd cladding layer were etched with this change. And what is necessary is to perform the 2nd dry etching and just to etch that of the 2nd cladding layer of the remaining about 0.2-micrometer thickness, as etching conditions are changed and it is shown in drawing 15 (b). By carrying out like this, further, there are few damages at the time of etching, and its controllability is good, and they can manufacture the semiconductor laser component which has a uniform property.

[0116] The desorption of aluminum 2O3 can be promoted by sputtering by increasing the amount of chlorine ion generation, without the amount of chlorine radical formation making it decrease, when aluminum is contained in the sample to etch according to this operation gestalt, even if aluminum 2O3 is formed of the residual moisture in a reaction chamber. Moreover, a chlorine radical and aluminum are made to react, and aluminum serves as an aluminum chloride and ****s. For this reason, the problem to which a sample is no longer etched into or an etching rate falls is avoidable.

[Translation done.]

DESCRIPTION OF DRAWINGS

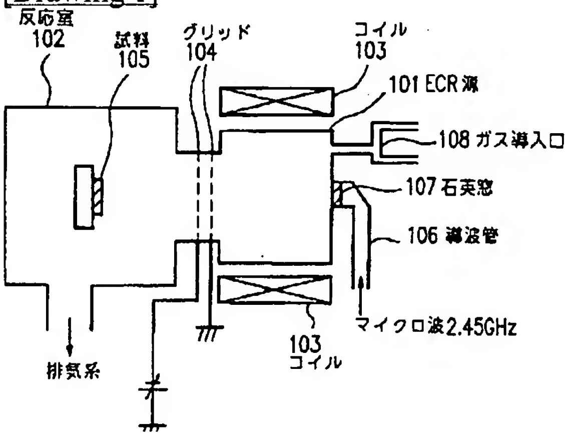
[Brief Description of the Drawings]
[Drawing 1] The mimetic diagram of ECR-RIBE equipment
[Drawing 2] (a) It is a sectional view after the dry etching [in / it reaches and / in (b) / 1 operation gestalt of this invention] of InP.
[Drawing 3] The sectional view after the dry etching of InP in 1 operation gestalt of this invention
[Drawing 4] The sectional view after the dry etching of InP in 1 operation gestalt of this invention
[Drawing 5] The sectional view after the dry etching of InP in 1 operation gestalt of this invention
[Drawing 6] The sectional view after the dry etching of InP in 1 operation gestalt of this invention
[Drawing 7] The configuration sectional view of the spin etching system for carrying out wet etching to homogeneity, rotating a substrate
[Drawing 8] The sectional view after the dry etching of InP in 1 operation gestalt of this invention
[Drawing 9] The configuration sectional view of the dry etching system equipped with the source of a radical beam, the source of an ion beam, and the ECR source
[Drawing 10] (a) - (c) -- 1 operation gestalt of this invention -- the sectional view of the diameter conversion laser of a spot to kick
[Drawing 11] (a) - (g) is the production process sectional view of the diameter conversion laser of a spot of drawing 10 .
[Drawing 12] (a) - (c) is the mimetic diagram of the two-step dry etching of different conditions in 1 operation gestalt of this invention.
[Drawing 13] (a) - (d) is the production process sectional view of the semiconductor laser in 1 operation gestalt of this invention.
[Drawing 14] (a) It is the configuration sectional view of semiconductor laser where it reaches and (b) compares the symmetric property of a ridge.
[Drawing 15] (a) It is the configuration sectional view of semiconductor laser where it reached and (b) was equipped with the monitor layer of the amount of etching into the cladding layer.
[Drawing 16] the spectrum of plasma luminescence -- drawing showing a result
[Description of Notations]
101 ECR Source
102 Reaction Chamber
103 Coil
104 Grid
105 Sample
702 Sample Maintenance Base
703 Nozzle
704 Etchant Tank
705 Reaction Chamber
902 Source of Radical Beam
903 Source of Ion Beam
904 ECR Source
9031 Drawer Electrode
1001 N-InP Substrate
1002 n-InP
1003 N-InGaAsP Cladding Layer

1004 Barrier Layer
1005 P-InGaAsP Cladding Layer
1006 Half--- Insulating InP
1007 P-InP Cap Layer
1008 N Lateral Electrode
1009 P Lateral Electrode
1010 Laser
1011 Spot-Size Transducer
1201 N-InP Substrate
1202 SiO2 Mask
1203 Processing Induction Damage Layer

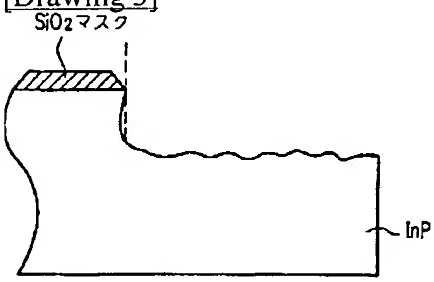
[Translation done.]

DRAWINGS

[Drawing 1]

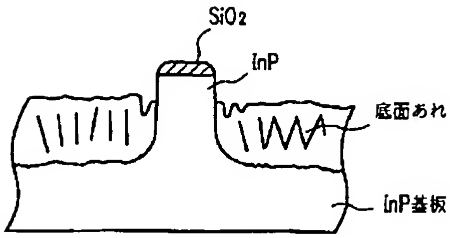


[Drawing 3]

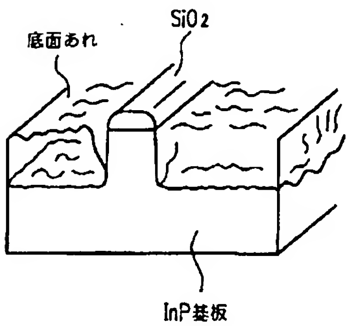


[Drawing 2]

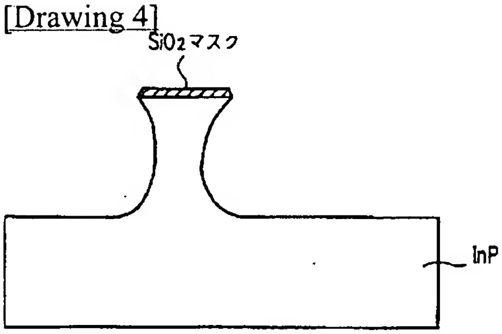
(a)



(b)



[Drawing 4]



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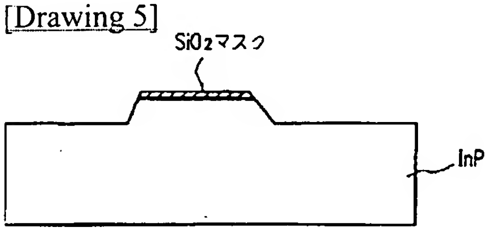
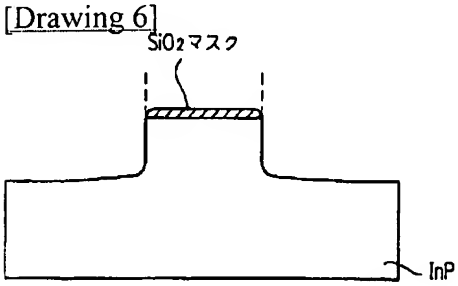
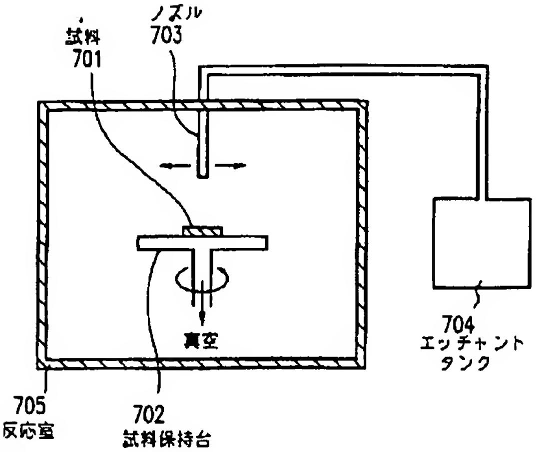


[Drawing 6]



[Drawing 7]



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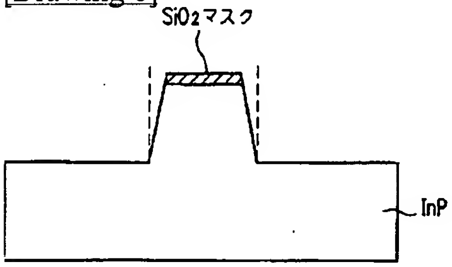
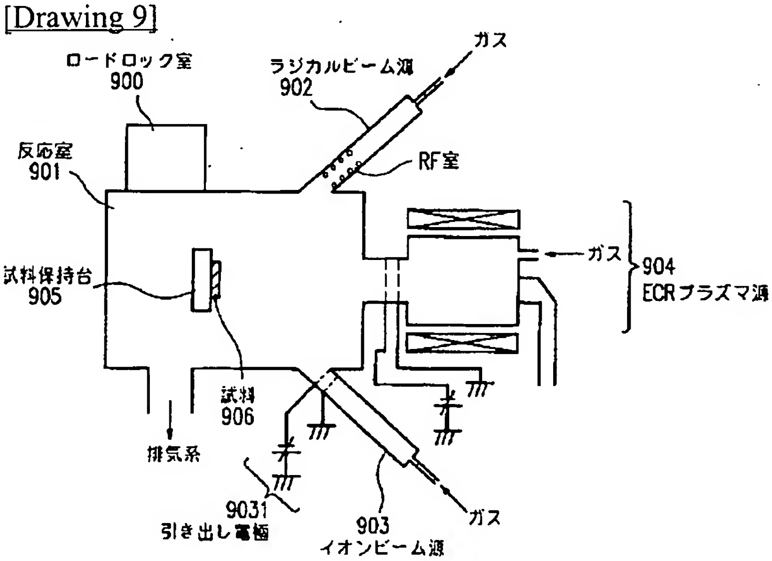
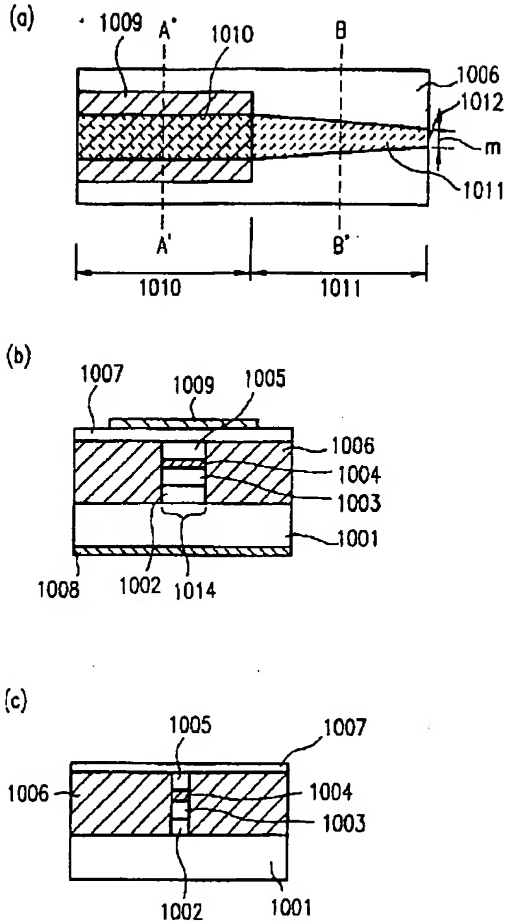


[Drawing 9]



[Drawing 10]


(a)
1009
A
1010
B
1006
1012
m
1011
A'
B'
1010
1011
(b)
1007
1009
1005
1006
1004
1003
1001
1008
1002
1014
(c)
1005
1007
1006
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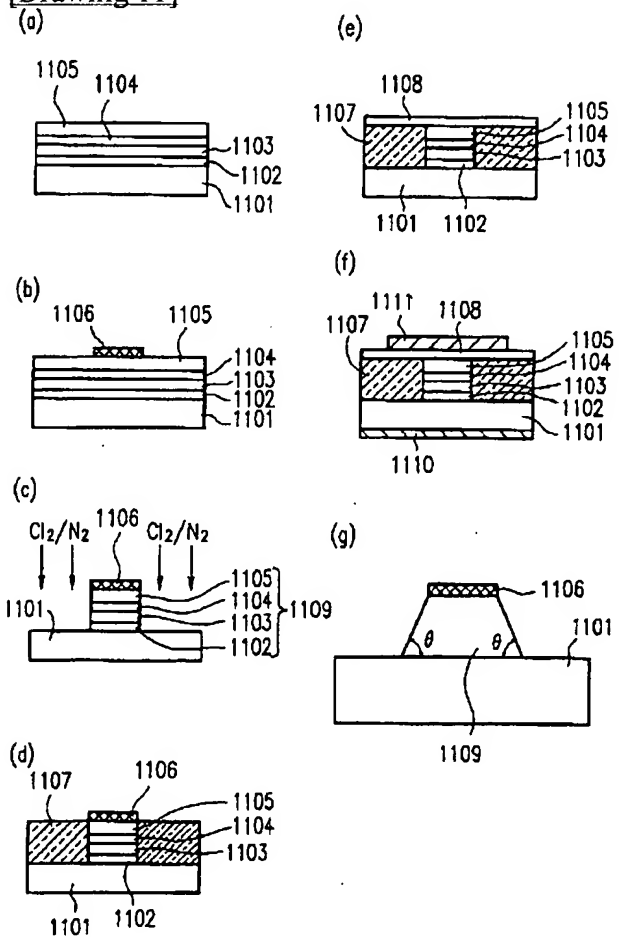
1003
1002
1001

[Drawing 11]


(a)
1105
1104
1103
1102
1101
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1106
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1102
1101
(c)
Cl2/N2
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Cl2/N2
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1105
1104
1103
1102
1109
(d)
1107
1106
1105
1104
1103
1101
1102
(e)
1108
1107
1105
1104
1103
1101
1102
(f)
1111
1108
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1105
1104
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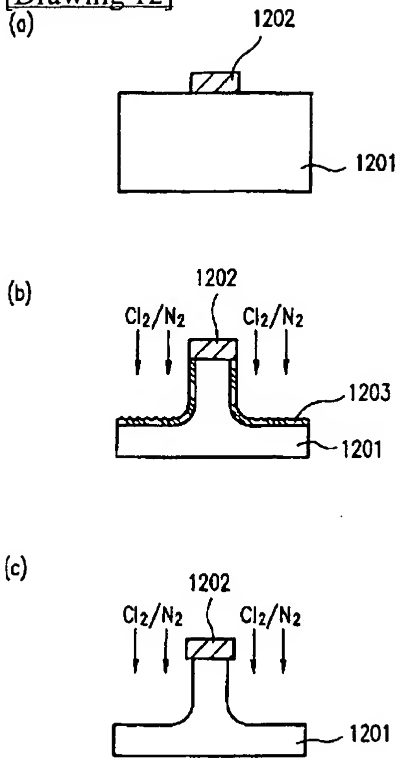
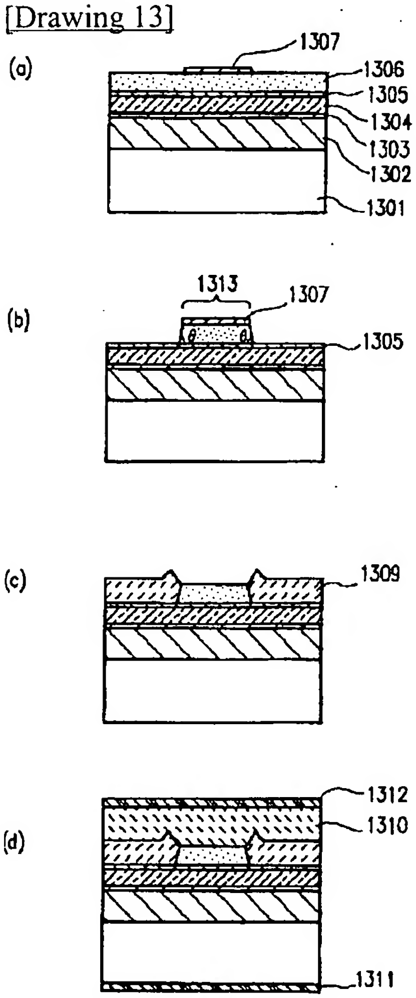
1101
1110
(g)
1106
θ
θ
1101
1109

[Drawing 12]

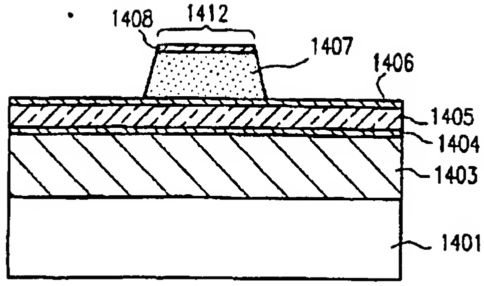


[Drawing 13]

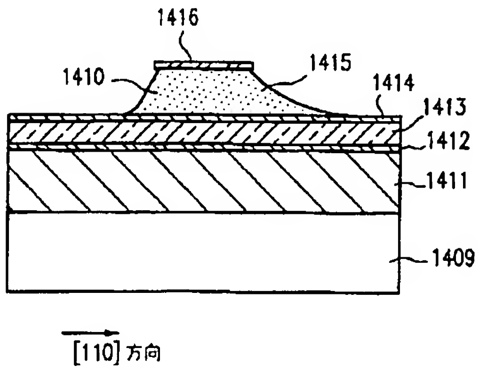


[Drawing 14]

(a)

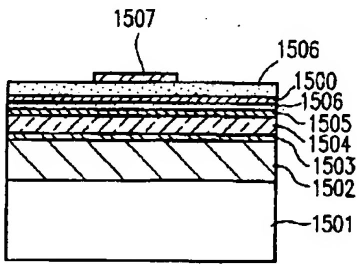


(b)

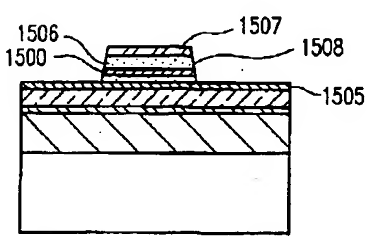


[Drawing 15]

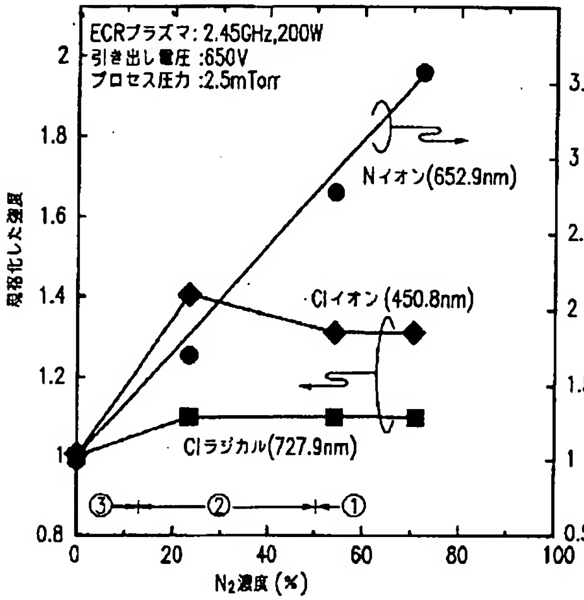
(a)



(b)



[Drawing 16]



[Translation done.]

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(30)Priority

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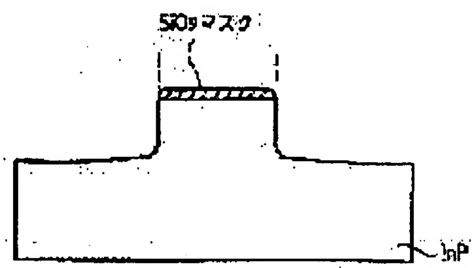
(54) ETCHING OF COMPOUND SEMICONDUCTOR, SEMICONDUCTOR LASER ELEMENT, AND MANUFACTURE THEREOF

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a method for dry-etching a compound semiconductor to form a vertical, smooth etched surface thereof.

SOLUTION: In the etching method, a dry etching apparatus having a plasma generation source for generating plasma having a density of about 1010cm-3 or more is used to subject a family III-V compound semiconductor or a family II-VI compound semiconductor to a dry etching process with use of a mixture of a gas containing halogen elements and a nitrogen gas. At this time, it is set to approximately satisfy a relationship of (flow rate of a gas containing halogen elements)/(flow rate of nitrogen gas) ≥ 1, and a pressure in the etching reaction is set at about 1mTorr or more.



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			21/306	Ｓ

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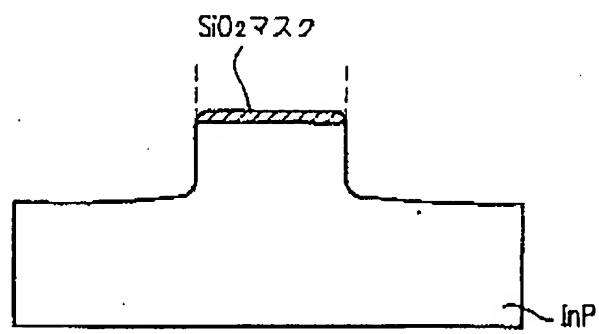
最終頁に続く

(54)【発明の名称】　化合物半導体のエッチング方法、半導体レーザ素子およびその製造方法

(57)【要約】

【課題】　化合物半導体のドライエッチングにおいて、垂直で平滑なエッチング面を形成する方法を提供する。

【解決手段】　本発明によるエッチング方法は、約10^{10}ｃm^{-3}以上の密度のプラズマを発生するプラズマ源を備えたドライエッチング装置によって、ハロゲン元素を含むガスと窒素ガスとの混合ガスを用いて、III-V族化合物半導体またはII-VI族化合物半導体をドライエッチングするエッチング方法であって、（ハロゲン元素を含むガスの流量）／（窒素ガスの流量）≧１程度であり、エッチング反応中の圧力は、約１mTorrまたは１mTorr以上である。



【特許請求の範囲】

【請求項１】　約$10^{10}cm^{-3}$以上の密度のプラズマを発生するプラズマ源を備えたドライエッチング装置によって、ハロゲン元素を含むガスと窒素ガスとの混合ガスを用いて、III-V族化合物半導体またはII-VI族化合物半導体をドライエッチングするエッチング方法であって、

（ハロゲン元素を含むガスの流量）／（窒素ガスの流量）≧１程度であり、

エッチング反応中の圧力は、約１mTorrまたは１mTorr以上である、エッチング方法。

【請求項２】　前記プラズマ源で発生したイオンを加速し、加速された該イオンの運動エネルギーにより、試料表面を加熱しながらエッチングする、請求項１に記載のエッチング方法。

【請求項３】　前記プラズマ源で発生したイオンを加速し、加速された該イオンの運動エネルギーにより、II－VI族化合物を含む試料の表面近傍のみを加熱し、該試料の支持台を冷却する、請求項１に記載のエッチング方法。

【請求項４】　試料支持台を加熱しながらエッチングする、請求項１に記載のエッチング方法。

【請求項５】　前記プラズマ源で発生したイオンを第１の加速電圧で加速して、エッチングする第１のドライエッチング工程と、

該第１のドライエッチング工程の後に行い、該プラズマ源で発生したイオンを第２の加速電圧で加速して、エッチングする第２のドライエッチング工程と、をさらに包含しており、該第１の加速電圧は、該第２の加速電圧より大きい請求項１に記載のエッチング方法。

【請求項６】　請求項１に記載のドライエッチングを行う第１のエッチング工程と、湿式エッチングを行う第２のエッチング工程と、を包含する請求項１に記載のエッチング方法。

【請求項７】　前記ドライエッチング装置は、ラジカルビーム源とイオンビーム源とを備えており、該ラジカルビーム源によって発生するラジカルの密度と、該イオンビーム源によって発生するイオンの密度と、をそれぞれ独立に制御しながらドライエッチングを行う、請求項１に記載のエッチング方法。

【請求項８】　前記化合物半導体は、$Al_xGa_yIn_{1-x-y}P$（$0<x\leqq1$、$0\leqq y\leqq1$）によって形成されている、請求項１に記載のエッチング方法。

【請求項９】　前記化合物半導体は、オフ基板上に形成されている請求項８に記載のエッチング方法。

【請求項１０】　約$10^{10}cm^{-3}$以上の密度のプラズマを発生するプラズマ源を備えたドライエッチング装置によって、ハロゲン元素を含むガスと窒素ガスとの混合ガスを用いて、III-V族化合物半導体またはII-VI族化合物半導体をドライエッチングするエッチング方法であって、

ハロゲンイオン密度をハロゲンラジカル密度より大きくして、エッチングする第１のドライエッチング工程と、

ハロゲンイオン密度をハロゲンラジカル密度より小さくして、エッチングする第２のドライエッチング工程と、

を包含するエッチング方法。

【請求項１１】　ラジカルビーム源と、イオンビーム源と、該ラジカルビーム源および該イオンビーム源と接続した反応室と、該反応室内に設けられた試料支持台と、ロードロック室とを備えたエッチング装置。

【請求項１２】　半導体基板上に、少なくとも１つの化合物半導体層をエピタキシャル成長する工程と、

該少なくとも１つの化合物半導体層上に、パターニングされたマスクを形成する工程と、

該マスクを用いて、該少なくとも１つの化合物半導体層に対して、請求項１～１０のいずれかに記載のエッチング方法を用いてエッチングを行い、リッジストライプを形成する工程と、

該リッジストライプを化合物半導体で埋め込む工程と、

を包含する半導体レーザ素子の製造方法。

【請求項１３】　前記基板は、傾斜基板であり、

前記少なくとも１つの化合物半導体層は、活性層と、該活性層を挟むｎ型ＡｌＧａＩｎＰクラッド層とｐ型ＡｌＧａＩｎＰクラッド層とを含んでおり、

前記リッジストライプは、該ｐ型ＡｌＧａＩｎＰ層を含んでいる、クレーム１２に記載の半導体レーザ素子の製造方法。

【請求項１４】　前記ｐ型ＡｌＧａＩｎＰクラッド層は、ｐ型ＡｌＧａＩｎＰ第１のクラッド層と、ｐ型ＡｌＧａＩｎＰ第２のクラッド層とを有しており、該第１のクラッド層と該第２のクラッド層との間に、エッチングストッパ層が形成されている、請求項１３に記載の半導体レーザ素子の製造方法。

【請求項１５】　前記ｐ型ＡｌＧａＩｎＰ第２のクラッド層の中には、該第２のクラッド層がエッチングされた量をモニタするための層が形成されている、請求項１４に記載の半導体レーザ素子の製造方法。

【請求項１６】　基板と、

該基板上に設けられており、活性層と、該活性層を挟むn型クラッド層とp型クラッド層と、を含むリッジストライプと、を備えた半導体レーザ素子であって、

該リッジストライプは、レーザ発振するレーザ部とテーパ状の先端部とを有し、

該リッジストライプの底面と、該リッジストライプの側面となす角度は、約60°以上90°以下である、半導体レーザ素子。

【請求項１７】　傾斜基板と、

該基板上に形成された、ｎ型ＡｌＧａＩｎＰクラッド層、活性層、およびｐ型ＡｌＧａＩｎＰクラッド層と、を備えた半導体レーザ素子であって、

該ｐ型ＡｌＧａＩｎＰクラッド層は、ほぼ対称的な形状

を持ったリッジ構造を有し、該リッジ構造の両側には、電流ブロック層が形成されている、半導体レーザ素子。

【請求項１８】　前記ｐ型ＡｌＧａＩｎＰクラッド層は、ｐ型ＡｌＧａＩｎＰ第１のクラッド層と、ｐ型ＡｌＧａＩｎＰ第２のクラッド層とを有しており、

該第１のクラッド層と該第２のクラッド層との間に、エッチングストッパ層が形成されている、請求項１７に記載の半導体レーザ素子。

【請求項１９】　前記ｐ型ＡｌＧａＩｎＰ第２のクラッド層の中には、該第２のクラッド層のエッチングされた量をモニタするための層が形成されている、請求項１８に記載の半導体レーザ素子。

【請求項２０】　前記先端部は、前記レーザ部の幅よりテーパ状に狭くなる幅を有する、該幅は約１μｍ以下である、請求項１６に記載の半導体レーザ素子。

【請求項２１】　前記先端部は、前記レーザ部の幅よりテーパ状に広くなる幅を有する、請求項１６に記載の半導体レーザ素子。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、化合物半導体、特にIII-V族またはII-VI族化合物半導体のドライエッチング方法、及びそれを用いて作製された半導体レーザ素子に関する。

【０００２】

【従来の技術】従来の化合物半導体のドライエッチング技術として、例えば、特開平７－６６１７５号公報に記載されている方法がある。この方法では、複合磁場型ＥＣＲ－ＲＩＢＥ（電子サイクロトロン共鳴－反応性イオンビームエッチング）装置を用いて、Ｉｎ系化合物半導体に対してドライエッチングを行う。複合磁場型ＥＣＲ－ＲＩＢＥ装置では、主コイルと副コイルの２つの機能のコイルが備えられており、エッチングする試料付近での磁場の発散が抑えられる。この方法によると、エッチングガスとしては、塩素と窒素が用いられる。塩素ガス/窒素ガスの流量比が１以下、内圧が0.5mTorrの条件で、エッチングマスクに対して、垂直な断面および平滑なエッチング面が得られる。

【０００３】上記公報によると、塩素ガス/窒素ガスを１以下の割合でガスを供給する場合、塩素ラジカルの発生が抑制され、塩素ラジカルより塩素イオンによるエッチングが優勢となる。このため、１０数eVの低いエネルギーを有するイオンを用いても、Ｉｎの塩化物とＰの塩化物の蒸発のバランスをとることができる。この結果、エッチングマスクに対して垂直な断面、および平滑なエッチング面が得られるエッチングが実現できる。

【０００４】

【発明が解決しようとする課題】従来、化合物半導体のドライエッチングにおいて、III族元素とエッチングガスとの反応物の蒸気圧と、Ｖ族元素とエッチングガスとの反応物との蒸気圧の差が大きいことに起因するエッチング面の荒れや、断面形状の制御が困難等の問題があった。

【０００５】上記特開平７－６６１７５号公報に開示されるドライエッチング技術も、この問題を解決するためのものである。この技術では、窒素ガスの添加により、塩素ガスが分解して、生成される塩素イオンと塩素ラジカルのうち、塩素ラジカルの生成量は、1/3程度にまで抑制されている。このことによって、上記問題を解決している。また、上記技術では、塩素ラジカルの生成量を最小にするため、反応室内の圧力を0.5mTorr以下にしている。この結果、Inの塩化物とPの塩化物の脱離速度が均衡になる。上記技術の特徴は、塩素ラジカル濃度が最小になる条件でエッチングを行うことである。上記公報は、塩素イオンの生成量とエッチング特性についての定量的なデータを示していない。

【０００６】また、エッチングする試料にＡｌが含まれている場合、反応室内の残留水分によりAl_2O_3が形成されることで、エッチングされなくなるか、エッチングレートが大きく低下する問題がある。

【０００７】本発明は、上記事情に鑑みてなされたものであって、その目的とするところは、III-V族及びII-VI族化合物半導体、さらにＡｌを含んでいるIII-V族化合物半導体に対して、窒素ガスを添加した塩素ガスを用いて、塩素ガスラジカル生成量を低減させることなく、垂直な断面および平滑なエッチング面が得られるドライエッチング方法を提供し、また、このドライエッチング方法を用いて作製された半導体レーザ素子およびその製造方法を提供することにある。

【０００８】

【課題を解決するための手段】本発明によるエッチング方法は、約10^{10}ｃｍ$^{-3}$以上の密度のプラズマを発生するプラズマ源を備えたドライエッチング装置によって、ハロゲン元素を含むガスと窒素ガスとの混合ガスを用いて、III-V族化合物半導体またはII-VI族化合物半導体をドライエッチングするエッチング方法であって、（ハロゲン元素を含むガスの流量）／（窒素ガスの流量）≧１程度であり、エッチング反応中の圧力は、約１mTorrまたは１mTorr以上であり、そのことにより上記目的が達成される。

【０００９】ある実施形態では、上記ドライエッチングを行う第１のエッチング工程と、湿式エッチングを行う第２のエッチング工程とを包含する。

【００１０】ある実施形態では、前記プラズマ源で発生したイオンを加速し、加速された該イオンの運動エネルギーにより、試料表面を加熱しながらエッチングする。

【００１１】ある実施形態では、前記プラズマ源で発生したイオンを加速し、加速された該イオンの運動エネルギーにより、II－VI族化合物を含む試料の表面近傍のみを加熱し、該試料の支持台を冷却する。

【0012】ある実施形態では、試料支持台を加熱しながらエッチングする。

【0013】ある実施形態では、前記プラズマ源で発生したイオンを第1の加速電圧で加速して、エッチングする第1のドライエッチング工程と、該第1のドライエッチング工程の後に行い、該プラズマ源で発生したイオンを第2の加速電圧で加速して、エッチングする第2のドライエッチング工程と、をさらに包含しており、該第1の加速電圧は、該第2の加速電圧より大きい。

【0014】ある実施形態では、前記ドライエッチング装置は、ラジカルビーム源とイオンビーム源とを備えており、該ラジカルビーム源によって発生するラジカルの密度と、該イオンビーム源によって発生するイオンの密度と、をそれぞれ独立に制御しながらドライエッチングを行う。

【0015】ある実施形態では、前記化合物半導体は、$Al_xGa_yIn_{1-x-y}P$（$0<x\leqq 1$、$0\leqq y\leqq 1$）によって形成されている。

【0016】ある実施形態では、前記化合物半導体は、オフ基板上に形成されている。

【0017】本発明による他のエッチング方法は、約$10^{10}cm^{-3}$以上の密度のプラズマを発生するプラズマ源を備えたドライエッチング装置によって、ハロゲン元素を含むガスと窒素ガスとの混合ガスを用いて、III-V族化合物半導体またはII-VI族化合物半導体をドライエッチングするエッチング方法であって、ハロゲンイオン密度をハロゲンラジカル密度より大きくして、エッチングする第1のドライエッチング工程と、ハロゲンイオン密度をハロゲンラジカル密度より小さくして、エッチングする第2のドライエッチング工程とを包含しており、そのことにより上記目的が達成される。

【0018】本発明によるエッチング装置は、ラジカルビーム源と、イオンビーム源と、該ラジカルビーム源および該イオンビーム源と接続した反応室と、該反応室内に設けられた試料支持台と、ロードロック室とを備えており、そのことにより上記目的が達成される。

【0019】本発明による半導体レーザ素子の製造方法は、半導体基板上に、少なくとも1つの化合物半導体層をエピタキシャル成長する工程と、該少なくとも1つの化合物半導体層上に、パターニングされたマスクを形成する工程と、該マスクを用いて、該少なくとも1つの化合物半導体層に対して、請求項1～10のいずれかに記載のエッチング方法を用いてエッチングを行い、リッジストライプを形成する工程と、該リッジストライプを化合物半導体で埋め込む工程と、を包含しており、そのことにより上記目的が達成される。

【0020】ある実施形態では、前記基板は、傾斜基板であり、前記少なくとも1つの化合物半導体層は、活性層と、該活性層を挟むn型AlGaInPクラッド層とp型AlGaInPクラッド層とを含んでおり、前記リッジストライプは、該p型AlGaInP層を含んでいる。

【0021】ある実施形態では、前記p型AlGaInPクラッド層は、p型AlGaInP第1のクラッド層と、p型AlGaInP第2のクラッド層とを有しており、該第1のクラッド層と該第2のクラッド層との間に、エッチングストッパ層が形成されている。

【0022】ある実施形態では、前記p型AlGaInP第2のクラッド層の中には、該第2のクラッド層がエッチングされた量をモニタするための層が形成されている。

【0023】本発明による半導体レーザ素子は、基板と、該基板上に設けられており、活性層と、該活性層を挟むn型クラッド層とp型クラッド層と、を含むリッジストライプと、を備えた半導体レーザ素子であって、該リッジストライプは、レーザ発振するレーザ部と、先端部とを有し、該リッジストライプの底面と、該リッジストライプの側面となす角度は、約60°以上90°以下であり、そのことにより上記目的が達成される。

【0024】ある実施形態では、前記先端部は、前記レーザ部の幅よりテーパ状に細くなる幅を有しており、該幅は約1μm以下である。

【0025】ある実施形態では、前記先端部は、前記レーザ部の幅よりテーパ状に広くなる幅を有する。

【0026】本発明による他の半導体レーザ素子は、傾斜基板と、該基板上に形成された、n型AlGaInPクラッド層、活性層、およびp型AlGaInPクラッド層と、を備えた半導体レーザ素子であって、該p型AlGaInPクラッド層は、ほぼ対称的な形状を持ったリッジ構造を有し、該リッジ構造の両側には、電流ブロック層が形成されており、そのことにより上記目的が達成される。

【0027】ある実施形態では、前記p型AlGaInPクラッド層は、p型AlGaInP第1のクラッド層と、p型AlGaInP第2のクラッド層とを有しており、該第1のクラッド層と該第2のクラッド層との間に、エッチングストッパ層が形成されている。

【0028】ある実施形態では、前記p型AlGaInP第2のクラッド層の中には、該第2のクラッド層のエッチングされた量をモニタするための層が形成されている。

【0029】

【発明の実施の形態】以下に、本発明の実施形態を詳細に説明する。

【0030】（第1の実施形態）本発明によるドライエッチング方法の第1の実施形態として、III－V族化合物半導体に対するドライエッチング方法を説明する。エッチングする試料として、InPが用いられる。エッチングガスとして、塩素ガスと窒素ガスを用いる。図1は、本実施形態で使用されるECR－RIBE装置（

子サイクロトロン共鳴－反応性イオンビームエッチング、以下、ＥＣＲ－ＲＩＢＥ装置と略称する）の構成を模式的に示す。この装置において、エッチングする試料の位置が、磁場を発生するコイルの外側にある。

【００３１】図１に示されるように、ＥＣＲ－ＲＩＢＥ装置は、主に、ＥＣＲ源１０１と、ＥＣＲ源につながっており、試料を設置するための反応室１０２と、排気ポンプ系（図示せず）とを備えている。ＥＣＲ源１０１では、イオン及びラジカルが生成される。ガス導入口108から、流量が制御された塩素ガスおよび窒素ガスが、ＥＣＲ源１０１に導入される。さらに、導波管106から、2.45ＧＨｚのマイクロ波が、石英窓107に面して、ＥＣＲ源１０１に導入され、塩素ガスおよび窒素ガスは励起状態になる。電子は、コイル１０３で発生した８７５ガウスの磁場に共鳴し、円運動をしながらガスと衝突を繰り返す。こうして、ＥＣＲ源１０１で発生した塩素イオンおよび窒素イオンは、グリッド１０４で加速されて、試料１０５に照射される。

【００３２】塩素イオンと窒素イオンは加速されて試料１０５に照射されるが、ＥＣＲ源１０１で発生する塩素ラジカルと窒素ラジカルは、イオン化されていないので、加速されない。しかし、塩素ラジカルと窒素ラジカルは、拡散により試料１０５の表面に到達し、エッチングに寄与する。このＥＣＲ－ＲＩＢＥ装置は、複合磁場型とは異なり、反応室１０２の側面には、コイルが設置されていない。このため、コイル１０３で発生する磁場は、発散磁場である。

【００３３】上述のように生じたイオン及びラジカルは、試料１０５表面に到達し、試料であるＩｎＰと反応して、Ｉｎ塩化物とＰ塩化物が生成する。Ｐ塩化物は、PCl_3の沸点が７６℃、PCl_5の沸点が１６２℃と低く、容易に気化する。

【００３４】一方、Ｉｎ塩化物は、ＩｎＣｌの沸点が６０８℃、$InCl_2$の沸点が５６０℃、$InCl_3$の沸点が６００℃と高く、気化しにくい。このため、試料１０５の表面には、Ｉｎ塩化物の層が形成される。ＥＣＲ源１０１から、加速された塩素イオンおよび窒素イオンが試料１０５の表面に衝突することで、Ｉｎ塩化物の気化は促進されるので、イオンの加速電圧が重要な要素となる。加速電圧３００Ｖ以下では、Ｉｎ塩化物は、気化が起こらずエッチングされない。

【００３５】表１は、本実施形態で用いられるエッチングの条件を示す。

【００３６】

【表１】

塩素	窒素	マイクロ波パワー	加速電圧	内圧	試料温度
3~20 SCCM	3.5~35 SCCM	200W(固定)	300~900 V	0.5~2.5 mTorr	室温 -300℃

【００３７】表１に示される条件において、加速電圧が約300V以上で、エッチングが最適である。なお、エッチングのためのマスクとして、SiO_2を使用している。

【００３８】以下に、表１に示される条件を用いて、ドライエッチングを行った主な結果を説明する。

【００３９】実験では、塩素流量を約１０SCCM、加速電圧を約６５０Ｖ、反応中の内圧を約２．５mTorr、試料温度を約２００℃に設定し、窒素流量を変化させてドライエッチングを行った。試料支持台を加熱し、試料温度を２００℃程度に維持することによって、III族化合物の蒸発を促進できる。

【００４０】窒素流量として、図２は約３５SCCM、図３は約７SCCM、図４は約３．５SCCMの条件でドライエッチングを行ったＩｎＰのそれぞれの断面写真を模式図に示す。

【００４１】図２（ａ）は、ＩｎＰ基板に対して、SiO_2マスクを用いてエッチングした断面を示す。この図から分かるように、ＩｎＰはエッチングされているが、底面（エッチング面）が非常に荒れている。図２（ｂ）は、図２（ａ）の斜視図である。図２（ｂ）からも、底面が荒れていることがよくわかる。図３の場合、ＳｉＯ［illegible］おり、また、底面荒れも殆どなくなっている。図４の場合、底面荒れはなく、エッチング面は平滑である。ただし、マスクの下側もエッチングされるサイドエッチングが起こり、マスクに対して、垂直なエッチングはできていない。

【００４２】上記結果から、塩素流量/窒素流量が約０．２９から１．４３の間に、エッチング面が荒れるか否かの境界があることがわかる。実験によると、その境界の塩素流量/窒素流量の比は、約１．０付近であることがわかった。また、塩素流量/窒素流量の比が約2.85付近で、エッチング面の平滑性が一番よいことがわかる。

【００４３】しかしながら、図４の断面形状を見ると、垂直でなく、サイドエッチングがかなり入っている。垂直な断面を得るためには、ドライエッチングにおける化学反応成分を抑える必要がある。そこで、試料温度を約１００℃に下げてエッチングを行った。その結果は、図５に示される（温度以外の条件は図４の場合と同じである）。

【００４４】試料温度を１００℃に下げることにより、化学反応性よりスパッタ成分が強くなり、SiO_2マス［illegible］

動）してしまう。このため、オーバーエッチングが起こり、台形の断面形状になる。ただし、エッチング面が非常に平滑であるので、台形の断面でも実用上問題はない。

【0045】図4および5から分かるように、エッチングにおける化学反応成分がスパッタ成分より優勢である場合に、サイドエッチが起こり、スパッタ成分が化学反応性より優勢である場合には、マスクが後退して、オーバーエッチが起こる。

【0046】次に、垂直な断面を得るためのエッチング条件の検討について説明する。

【0047】化学反応性を増加させるために試料温度を約150℃にし、エッチングレートを向上させるために塩素の供給量を約11．5SCCMまで増やして（窒素流量は図4の場合と同じく3．5SCCM）、エッチングを行った。その結果は、図6に示される。図6から分かるように、スパッタ成分と化学反応成分のバランスがとれ、垂直なエッチング断面が実現される。この場合、加速電圧は約650V、内圧は約2.5mTorrのままである。

【0048】図2～6の場合のそれぞれのエッチング条件は、まとめて表2に示す。

【0049】

【表2】

	塩素 (SCCM)	窒素 (SCCM)	塩素／窒素流量比	加速電圧 (V)	内圧 (mTorr)	試料温度 (℃)
図2	10	35	0.29	650	2.5	200
図3	10	7	1.43	650	2.5	200
図4	10	3.5	2.8	650	2.5	200
図5	10	3.5	2.8	650	2.5	100
図6	11.5	3.5	3.29	650	2.5	150

【0050】塩素流量/窒素流量の比が約1．0以上であれば、エッチング面は荒れない。しかし、この流量比を6．4以上に大きくすると、エッチング面は、また少し荒れ始める。エッチング面の荒れを考慮して、塩素流量/窒素流量の流量比の最適値は、約1．0～6．4の範囲である。

【0051】図16は、プラズマ発光の分光結果を示す。この分光結果は、窒素濃度に対する窒素イオン、塩素イオン、および塩素ラジカルの強度変化を表す。図16に示される各発光強度は、塩素ガスのみのプラズマ発光強度で規格化されている。窒素イオンは652.9nm、塩素イオンは450.8nm、塩素ラジカルは727.9nmでの発光が観測された。塩素ガスのみの場合の652.9nmでの発光は、雑音であり、窒素イオンによる発光ではない。

【0052】窒素イオンの発光強度は、窒素の添加量に比例して単純に増加する。塩素イオンによる発光強度は、窒素の添加によって増加するが、窒素の添加濃度が約23%で最大値を示す。この最大値は、窒素無添加の場合の約1.4倍である。その後、窒素添加濃度の増加に従って、塩素イオンによる発光強度は、少し減少し、窒素無添加の場合の約1.3倍の値で飽和する。塩素ラジカルによる発光強度は、窒素の添加によって、約10%増加するが、この程度で飽和し、さらに窒素を添加しても増加しない。

【0053】以下に、上記発光強度の変化を、エッチング特性と比較して説明する。

【0054】塩素流量／窒素流量が1未満の場合は、図16での窒素濃度が50%を越える領域（領域①）である。領域①では、…（窒素無添加）の場合に比して、塩素イオン強度は約1.3倍以上になっているが、窒素イオン強度は約3倍になっている。つまり、過剰な窒素イオンにより、In塩化物及びP塩化物のうち、蒸気圧の高いP塩化物が選択的にスパッタされることによって、エッチング面が荒れると考えられる。

【0055】塩素流量／窒素流量が約1以上6.4以下の場合は、図16の窒素濃度が約13%以上約50%以下の領域（領域②）に相当する。この領域では、窒素イオンの強度は、それほど増加しておらず、In塩化物及びP塩化物の表面からの脱離の均衡がとれ、平滑なエッチング面が実現されている。

【0056】塩素流量／窒素流量が6.4を越える場合は、図16の窒素濃度が約13%以下の領域（領域③）に相当する。領域③の場合、再びエッチング面が荒れる。これは、生成したIn塩化物及びP塩化物の脱離はスパッタ効果より主に熱エネルギーにより起こるため、P塩化物の選択的な脱離が起こるからであると考えられる。

【0057】以上述べたように、本発明において、窒素ガスを添加する効果は、塩素イオンの生成を促進するだけでなく、窒素イオン自体によるスパッタ効果によって、III族あるいはV族の塩化物の脱離を促進するところに大きな特徴がある。これは、II-VI族化合物半導体に本発明を適用した場合にも、同様である。

【0058】以上の説明では、エッチングする材料として、III－V族化合物半導体のＩｎＰを用いたが、後で説明するように、ＩｎＰの代わりに、ＡｌＧａＩｎＰ系、ＡｌＧａＩｎＮ系、また、II－VI族化合物半導体のＺｎＭｇＳＳｅ系の材料を用いてもよい。また、エッチ

エッチングは可能である。

【００５９】（第２の実施形態）以下に、本発明によるドライエッチング方法の第２の実施形態として、III－V族化合物半導体に対するドライエッチング方法を説明する。より具体的には、試料全体の温度を上昇させることなく、加速されたイオンの運動エネルギーにより、試料表面のみを加熱しながら、エッチングするドライエッチング方法を説明する。

【００６０】エッチング試料としてＩｎＰが用いられ、エッチングマスクとしてＳｉO_2が用いられる。なお、本実施形態の方法は、II－VI族化合物半導体のエッチングに適用できる。

【００６１】上記第１の実施形態で述べたように、試料温度を上昇させる場合、ドライエッチングにおける化学反応成分がスパッタ成分より優勢になり、マスクの下側もエッチングされるサイドエッチングが起こる。ところが、試料温度を下げると、スパッタ成分が強くなるので、マスクが後退するオーバーエッチを起こしたり、エッチング底面が荒れたりする。

【００６２】そこで、本実施形態では、試料をＡｌで作製した試料保持治具に密着させ、この保持治具を冷却しながらエッチングする。

【００６３】ＥＣＲ源で発生するイオンは、グリッドで数百Vで加速され、運動エネルギーを持って試料に照射される。ＥＣＲ源で発生するラジカルは、加速されない。ラジカル１個当たりのエネルギーは、20～30eVと小さいが、発生するラジカル数が多いため、試料表面がラジカルから受け取る全エネルギーは、かなり大きい。このように、試料表面が多数のイオン、ラジカルのエネルギーを得るため、試料基板の温度を上昇しなくとも、試料自体を数百℃まで上昇させた場合と同様な効果が得られる。すなわち、このように試料の表面を加熱することによって、III族またはII族の塩化物の蒸発を促進し、エッチングレートを向上する。

【００６４】図8は、ＥＣＲ－ＲＩＢＥ装置を使用し、塩素流量を約11.5SCCM、窒素流量を約３．５SCCM、マイクロ波パワーを約200W、内圧を約2.5mTorr、加速電圧を約650Vにして、ＩｎＰに対してドライエッチングを行った場合のＩｎＰの断面を示す。

【００６５】この場合、試料全体に対して、加熱していない。試料は、Ａｌで作製した試料保持治具に装着されている。試料保持治具は、水冷された試料支持台に載せられる。このことによって、試料の表面近傍の部分だけが加熱され、この部分を除いた部分の温度は、上昇しない。試料は、熱的ダメージから保護される。こうすることは、特にII－VI族化合物を含む試料をエッチングするのに有効である。なぜなら、II－VI族化合物半導体の結晶成長温度（約２６０℃）が低いため、結晶性の劣化を防止するためには、エッチング温度を結晶成長温度より低く（約２５０℃以下）する必要がある。

【００６６】上記第１の実施形態で述べたように、エッチング断面の形状は、エッチングするスパッタ成分と化学反応成分のバランスを反映する。すなわち、スパッタ成分が優勢の場合に断面はオーバーエッチされ、化学反応成分が優勢の場合にはサイドエッチングが起こる。

【００６７】図８から分かるように、本実施形態によると、試料全体の温度が室温付近であるにも関わらず、断面はほぼ垂直であり、化学反応成分とスパッタ成分のバランスがとれている。図８の断面は、試料温度を150℃に設定してエッチングを行った場合、すなわち、図６の場合と同じ断面形状を示す。つまり、加熱せずにエッチングを行った図８に示される結果は、断面形状に関して、試料温度を150℃に設定してエッチングを行った図６に示される結果と同じである。ただし、図８の場合のエッチングレートは、図６の場合のそれより25%低い。

【００６８】なお、本実施形態では、試料温度は室温付近に設定されているが、試料支持台を0℃以下に冷却して、Ｖ族の塩化物の昇華を抑制することにより、III族の塩化物との昇華の差を小さくすることもできる。このことによって、垂直な断面、および平滑なエッチング面が得られるドライエッチングを行うことができる。

【００６９】（第３の実施形態）本発明によるドライエッチング方法の第３の実施形態として、III－V族化合物半導体に対するドライエッチング方法を説明する。より具体的には、異なる条件の２段階のエッチングを行うドライエッチング方法を説明する。試料としてＩｎＰ、エッチングマスクとしてＳｉO_2、エッチングガスとして塩素と窒素を用いる。

【００７０】ＥＣＲ－ＲＩＢＥ装置を用い、まず、第１のドライエッチングを行う。この第１のドライエッチングにおいては、内圧を約１mTorr以下、加速電圧を約300V以上にすることでガス分子間の衝突を抑え、ラジカル密度よりもイオン密度を大きくする。塩素流量/窒素流量は約１以上、試料温度は約１００℃に設定される。この場合、化学反応成分よりスパッタ成分によるエッチングが優勢になり、試料表面に対して垂直な方向における高速なドライエッチングが進み、所望の形状に近い形状が形成される。

【００７１】上記第１のドライエッチングは、約1000Å/分以上と比較的高いエッチングレートを有する。高速でエッチングを行う場合、エッチングされた側面またはエッチング面において、加工に誘起される損傷が生じたり、エッチング面が荒れたりする。これは、ＥＣＲ源で発生するハロゲンイオンが300V以上の高い電圧で加速され試料に照射されることによって、試料に結晶欠陥が生じるからである。また、ハロゲン化物の沸点がIII族（またはII族）とV族（またはVI族）で異なるため、エッチング面におけるストイキオメトリがずれることによって、エッチング面におけるIII族（またはII族）元素がV族（またはVI族）元素より過剰に多くなるからであ

る。

【００７２】次に、第１のドライエッチングに引き続き、第２のドライエッチングを行う。この第２のドライエッチングを行う目的としては、第１のドライエッチングにより生じた加工誘起損傷を持つ層を除去することである。また、第１のドライエッチングで、エッチング面に荒れが生じた場合に、荒れた面を除去して平滑にすることである。上記目的を達成するために、第２のドライエッチングは、塩素流量/窒素流量を約3以上、内圧を約2mTorr以上、加速電圧を約300V以下、試料温度を約２００℃に設定して行う。この場合、ガス分子間の衝突が増え、イオン密度よりラジカル密度のほうが大きくなる。さらに、平均自由行程が小さくなるので、スパッタ成分より化学反応成分のほうが強く作用する。

【００７３】上記のような化学反応性の強い条件下でのエッチングは、結晶に与える加工誘起損傷が小さいので、第１のドライエッチングで生じた加工誘起損傷を多く含んだ層を除去することができる。第１のドライエッチングでエッチング面が荒れた場合、上記第２のドライエッチングにより、荒れた面をより平滑にすることができる。

【００７４】第１のドライエッチングは、塩素流量 /窒素流量約≧1、内圧約≦1mTorr、加速電圧約≧300Vの条件で行うことができるが、最適条件として、塩素流量/窒素流量約≧3、内圧約≦0.5mTorr、加速電圧約≧600Vの方がより望ましい。

【００７５】第２のドライエッチングは、塩素流量/窒素流量約≧3、内圧約≧2mTorr、加速電圧約≦300Vの条件で行うことができるが、最適条件として、塩素流量/窒素流量約≧10、内圧約≧3mTorr、加速電圧約≦100Vの方がより望ましい。

【００７６】図１２は、本実施形態によるドライエッチングの工程を示す断面図である。まず、図１２（ａ）に示されるように、ＩｎＰ基板１２０１上に、パターニングされたＳｉＯ２マスク１２０２を形成する。その後、図１２（ｂ）に示されるように、第１のドライエッチングを行う。この工程によって、加工に誘起される損傷層１２０３がエッチング表面に生じる。次に、図１２（ｃ）に示されるように、第２のドライエッチングを行う。第２のドライエッチングにおいて、第１のドライエッチングの場合より、塩素イオン密度が小さく、塩素ラジカル密度が大きい。第２のドライエッチングを行うことによって、加工に誘起される損傷層１２０３が除去され、マスク１２０２に対して垂直な側面、平滑なエッチング面が形成できる。

【００７７】なお、以上の説明では、内圧、流量比及び加速電圧を変えることによって、第１および第２のドライエッチングにおける塩素イオン密度と塩素ラジカル密度との大小関係を変えた。この代わり、加速電圧のみを変えることによって、第１と第２のドライエッチングを行ってもよい。すなわち、第１、第２のドライエッチングとも、塩素流量 /窒素流量約≧3、内圧約≧2mTorr、試料温度約200℃の条件を用い、第１のドライエッチングでは加速電圧を約900V、第２のドライエッチングでは加速電圧を約100Vに設定する。このような条件で、ドライエッチングを行っても、荒れのないエッチングが実現できる。

【００７８】（第４の実施形態）以下に、本発明によるエッチング方法の第４の実施形態として、III－Ｖ族化合物半導体に対するエッチング方法を説明する。より具体的には、ドライエッチングとウエットエッチングの２段階のエッチングを行うエッチング方法について説明する。試料としてＩｎＰ、エッチングマスクとしてＳｉＯ$_2$を、エッチングガスとして塩素と窒素を用いる。ウエットエッチングのエッチング溶液として、塩酸、酢酸、過酸化水素水を用いる。

【００７９】まず、ＥＣＲ－ＲＩＢＥ装置を用い、第１のエッチング（ドライエッチング）を行う。この第１のエッチングにおいて、塩素流量/窒素流量を約≧1、内圧を約2mTorr以上、加速電圧を約300V以上、試料温度を約100℃以上にする。第１のエッチングは、上記条件で可能であるが、最適条件は、塩素流量が約11.5SCCM、窒素流量が約3.5SCCM、試料温度が約150℃、加速電圧が約650V、内圧が約2.5mTorrである。このような条件で、試料を所定の形状に加工できる。第１のエッチングで発生する加工誘起損傷を含んだ層は、以下に説明する第２のエッチングにより除去される。

【００８０】図７は、第２のエッチングに用いられるスピンエッチング装置の構成を模式的に示す。第２のエッチング、すなわち、ウエットエッチングは、反応室７０５の中で行われる。上記ドライエッチングされた試料７０１は、試料保持台７０２上に設置される。試料保持台７０２は、試料７０１を真空チャックで保持し、所定の回転速度で回転する。エッチャントタンク７０４に所定の温度に維持され保存されている塩酸、酢酸、および過酸化水素水の混合液は、ノズル７０３から出て、試料７０１上に流れ落ちる。ノズル７０３と試料保持台７０２の中心は一致しており、ノズル７０３は試料保持台７０２の中心から、試料保持台の半径方向に所定の距離までの間を往復運動する。ノズル７０３が、回転する試料７０１に液を流れ落としながら、半径方向を往復運動することにより、極めて均一なウエットエッチングが行われる。こうして、第１のエッチングで生じた加工に誘起される損傷層が除去される。塩酸、酢酸、過酸化水素水の混合比は3：36：1、混合液の温度は20℃であればよい。

【００８１】ウエットエッチングはスパッタ成分を含まないので、ドライエッチングを用いることによって与えられるような多少のダメージも、ウエットエッチングを用いることによって防止できる。このため、さらにエッチング面の平滑性を向上できる。

【００８２】本実施形態において、第２のエッチングに使用する溶液として、塩酸、酢酸、および過酸化水素水を用いたが、これに代えて、硫酸、過酸化水素水、および水の混合液、塩酸およびリン酸の混合液、または飽和臭素水およびメタノールの混合液を用いてもよい。要は、第１のエッチングにより生じた加工に誘起され損傷層を除去できる溶液であればよい。

【００８３】（第５の実施形態）以下に、ＥＣＲ源のほかに、ラジカルビーム源およびイオンビーム源を備えたドライエッチング装置、およびそれを用いたドライエッチング方法について説明する。

【００８４】図９は、本実施形態のドライエッチング装置の構成を模式的に示す。この装置は、ＥＣＲ源９０４、反応室９０１のほかに、ラジカルビーム源９０２、およびイオンビーム源９０３を備えている。ラジカルビーム源９０２およびイオンビーム源９０３は、反応室９０１に接続されている。

【００８５】反応室９０１中には、試料９０６を保持する試料保持台９０５が備えられている。ラジカルビーム源９０２で生成された塩素ラジカル、イオンビーム源９０３で生成された塩素イオン及びＥＣＲ源９０４で生成された塩素イオン、塩素ラジカル、窒素イオンは、試料９０６に照射される。試料９０６は、試料９０６を反応室９０１に入れるためのロードロック室９００から、反応室９０１に送られる。反応室９０１は、排気系（図示せず）により約10^{-6}Torr以下に排気される。

【００８６】ラジカルビーム源９０２では、塩素ガスは、RF高周波が加えられ、プラズマ状態となる。これによって、塩素イオンと塩素ラジカルが発生する。塩素イオンは、加速されない場合、平均自由行程が数センチメートルであるから、ラジカル源９０２または反応室９０１の中で他の原子または電子と衝突して消滅するので、試料まで到達しない。生成したラジカルは、拡散により試料表面にまで到達し、反応に寄与する。

【００８７】一方、イオンビーム源９０３でも、塩素ガスは、RF高周波が加えられ、プラズマ状態となる。これによって、塩素イオンと塩素ラジカルが発生する。引き出し電極９０31に加える電圧を変化させることにより、イオンビーム源９０３から引き出される塩素イオンと塩素ラジカルの割合を変えることによって、塩素イオンを塩素ラジカルより多く引き出し、試料表面に照射する。

【００８８】ＥＣＲ源９０４では、第１の実施形態で述べたように、ガスが分解され、イオンとラジカルが生成される。本実施形態において、窒素ガスをＥＣＲ源９０４に導入する。

【００８９】上記のようにイオン源、ラジカル源及びＥＣＲ源を備えることにより、反応に寄与するガスの、平滑性に寄与するラジカルの密度と、エッチングレートに寄与するイオンの密度をそれぞれ独立に制御できる。このため、エッチング面の平滑性を保ったまま、高速なエッチングが可能である。エッチングレート、断面形状、エッチング面の平滑性を制御しやすくなる。SiO_2をマスクとして用い、塩素と窒素の混合ガスによるＩｎＰのドライエッチングの場合、第１の実施形態で述べたように、Ｐ塩化物は容易に昇華し、Ｉｎ塩化物は昇華しにくいため、試料表面にＩｎ塩化物の層が形成されることになる。このＩｎ塩化物の層を昇華させるには、加速された塩素イオン及び窒素イオンの運動エネルギーを利用すればよい。

【００９０】そこで、塩素イオン流量を塩素ラジカル流量より多くし、塩素イオンと窒素イオンを約300V以上の高電圧で加速して供給すればよい。エッチングレートを高くするためには、試料温度を約150℃以上に設定すればよい。

【００９１】本実施形態によると、ラジカルビーム源からの塩素ラジカル流量が約１SCCM以上、イオンビーム源からの塩素イオン流量が約１０SCCM以上、加速電圧が約３００V以上、ＥＣＲ源からの窒素イオンが約３SCCM以下で、平滑なエッチング面を持つInPのドライエッチングが可能である。さらに、塩素ラジカル流量が約1SCCM、塩素イオン流量が約10SCCM、塩素イオンの加速電圧が約600V以上、ＥＣＲ源の窒素流量が約3SCCM、試料温度が約150℃の条件で、垂直な断面と平滑なエッチング面を持つドライエッチングが実現する。

【００９２】（第６の実施形態）以下に、上記第１～５の実施形態で説明したエッチング方法を用いて、半導体レーザ素子の製造方法を説明する。半導体レーザ素子として、スポット径変換レーザを用いる。図１０（ａ）～（ｃ）は、スポット径変換レーザの構造の断面を模式的に示す。

【００９３】このスポット径変換レーザは、図１０（ａ）に示されるように、レーザ部１０１０と、スポットサイズ変換部（先端部）１０１１とを有する。レーザ部１０１０は、一定の幅と厚さを有するストライプ形状を有する。スポットサイズ変換部１０１１は、幅が出射端１０１２に向かって、テーパ状に幅が小さくなっている。レーザ光は、スポットサイズ変換部１０１１を導波する間に、レーザ部１０１０におけるスポット径から、スポットサイズ変換部１０１１の出射端（先端部１０１１の先端）１０１２の径ｍに変換される。出射端１０１２は、幅ｍが約１μm以下（典型的には、約０．６μm）、断面の角度が約90°である。

【００９４】図１０（ｂ）は、図１０（ａ）の線A－A'に沿った断面を示す。図１０（ｂ）に示されるように、n-InP基板１００１上に順次、n-InP層１００２、n-InGaAsPクラッド層１００３、活性層１００４、p-InGaAsPクラッド層１００５、およびp-InPキャップ層１００７がエピタキシャル成長されている。これらの層はメサストライプ（リッジストライプ）１０１４を構成し、メサス

トライプ１０１４は半絶縁性ＩｎＰ１００６によって埋め込まれている。p-InPキャップ層１００７上に、ｐ側電極１００９が形成されており、基板１００１の裏面の全面に、ｎ側電極１００８が形成されている。

【００９５】p側電極１００９から注入された正孔は、ｎ側電極１００８から注入された電子と活性層１００４で再結合する。発光はｐ側電極１００９の下で起こり、共振器端面で閉じ込められることによって、レーザ発振する。

【００９６】図１０（ｃ）は、図１０（ａ）の線B−B'に沿った断面を示す。図１０（ｂ）と図１０（ｃ）を比較して分かるように、レーザ部１０１０とスポットサイズ変換部１０１１とでは、活性層１００４の幅が異なる。つまり、スポットサイズ変換部１０１１の活性層１００４の幅の方が、小さくなっている。

【００９７】以下に、図１１（ａ）～（ｇ）を参照しながら、スポット径変換レーザの製造方法を示す。図１１（ａ）～（ｇ）は、レーザ部１０１０の断面の模式図である。スポットサイズ変換部１０１１は、活性層の幅等が異なるだけで、レーザ部１０１０と同時に製造される。

【００９８】まず、図１１（ａ）に示されるように、有機金属気相成長法（ＭＯＶＰＥ法）によって、n-InP基板１１０１上に、n-InP層１１０２、n-InGaAsPクラッド層１１０３、活性層1１０４、p-InGaAsPクラッド層１１０５を順次成長させる。その後、図１１（ｂ）に示されるように、p-InGaAsPクラッド層１１０５上に、所定の形状を有するＳｉO_2マスク１１０６を形成する。

【００９９】次に、図１１（ｃ）に示されるように、上記第１～５の実施形態で説明したエッチング方法によって、ＥＣＲ−ＲＩＢＥ装置を用いて、メサストライプ（リッジストライプ）１１０９を形成する。エッチングの条件は、塩素流量/窒素流量約≧1、マイクロ波パワー約200W、内圧約2mTorr以上、試料温度約150℃以上、加速電圧が約300V以上である。この条件で形成されるメサストライプの、側面と基板１１０１の表面となす角度θは、図１１（ｃ）および（ｇ）に示されるように、約60°以上90°以下である。次に、図１１（ｄ）に示されるように、ＭＯＶＰＥ法によって、ＳｉO_2マスク１１０６を選択成長のマスクとして用いて結晶成長を行い、メサストライプ１１０９を半絶縁性InP１１０７で埋め込む。ＳｉO_2マスク１１０６を除去した後、図１１（ｅ）に示されるように、ＭＯＶＰＥ法でp-InGaAsPキャップ層１１０８を成長する。最後に、図１１（ｆ）に示されるように、p側電極１１１１とn側電極１１１０を蒸着し、熱処理を行いオーミック接触を形成する。

【０１００】以上説明したように、本発明によると、ＥＣＲ−ＲＩＢＥ装置で、塩素ガスと窒素ガスを用いてエッチングを行うことによって、図１１（ｇ）に示すようあるメサストライプの側壁と、幅約１μm以下の出射口を持つキャビテイと導波路を形成することができる。本発明の方法によると、素子の信頼性を低下する逆メサ（上記角度θが９０°以上）が形成されることを回避できる。

【０１０１】なお、上記説明では、先端部１０１１の幅は、レーザ部１０１０の幅よりテーパ状に狭くなっているが、レーザ部１０１０の幅よりテーパ状に広くなってもよい。

【０１０２】以上の実施形態において、ＥＣＲ−ＲＩＢＥ装置を用いたが、これに代えて、誘導結合型プラズマ源を備えたドライエッチング装置、ヘリコン型プラズマ源を備えたドライエッチング装置、またはＮＬＤ型プラズマ源を備えたドライエッチング装置を用いてもよい。

【０１０３】また、以上の実施形態で、化合物半導体として、ＩｎＰを用いて説明したが、他のIII-V族またはII-VI族化合物半導体を用いてもよい。なお、以上の説明では、塩素ガスを用いたが、塩素、臭素、またはヨウ素を含んだガスを用いてもよい。

【０１０４】（第７の実施形態）以下に、図１３（ａ）～（ｄ）を参照しながら、上記第１～５の実施形態で説明したエッチング方法を用いて、他の半導体レーザ素子の製造方法を説明する。本実施形態において、エッチングされる化合物半導体は、アルミニウム（Ａｌ）を含んでいる。

【０１０５】まず、図１３（ａ）に示されるように、ＭＯＶＰＥ法により、ｎ型ＧａＡｓ基板１３０１上に、ｎ型ＧａＡｓバッファ層（不図示）、ｎ型Ａｌ$_x$Ｇａ$_y$Ｉｎ$_{1-x-y}$Ｐ（０＜ｘ≦１、０≦ｙ≦１、以下、ＡｌＧａＩｎＰ と略称する）クラッド層１３０２、ＡｌＧａＩｎＰ障壁層とＧａＩｎＰ井戸層とによって構成される多重量子井戸活性層１３０３、ｐ型ＡｌＧａＩｎＰ第１のクラッド層１３０４、ＧａＩｎＰエッチングストッパ層１３０５（厚さ：５ｎｍ程度）、ｐ型ＡｌＧａＩｎＰ第２のクラッド層１３０６をエピタキシャル成長させる。ＧａＡｓ基板１３０１は、（１００）面から[１１０]方向へ１０度程度傾斜しているオフ基板である。

【０１０６】次に、リッジを形成するために、ｐ型ＡｌＧａＩｎＰ層１３０６上に、パターニングされた幅約４μm、厚さ約０．５μmのＳｉO_2マスク１３０７を形成する。

【０１０７】次に、図１３（ｂ）に示されるように、上記第１～５で説明したドライエッチング方法を用いて、ＳｉO_2マスク１３０７をエッチングマスクとして、リッジ１３１３を形成する。エッチングの条件として、塩素流量を約１１SCCM、窒素を約３．５SCCMにすることによって、塩素流量／窒素流量比を、約３．１に設定する。なお、加速電圧は約６５０V、内圧は約２．５mTorr、試料温度は約１００℃である。このような条件でド

のリッジ１３１３が得られる。

【０１０８】通常、傾斜基板を用いるエッチングでは、図１４（ｂ）に示すように、リッジは左右対称の形状にならない。基板が（１００）面から傾斜しているため、硫酸系のエッチング液を用いるウエットエッチングでは、リッジの底部における側面の傾斜が緩やかとなり、リッジは非対称な形状となる。その結果、活性層へのキャリアの注入および光の閉じ込めが不均一になり、横モードが不安定になる。特に、レーザを高温で動作させるときには、このことは顕著になる。

【０１０９】また、ＡｌＧａＩｎＰ系の半導体レーザでは、レーザ光の波長を短波長化するためには、傾斜角度をますます大きくしている。傾斜角度が大きくなればなるほど、リッジの非対称性が大きくなる。本実施形態によると、図１４（ａ）に示されるように、上記条件でドライエッチングを行うことによって、オフ基板を用いるにもかかわらず、対称な形状を持ったリッジ１４１２を形成できる。

【０１１０】リッジ形成するためのドライエッチングは、図１３（ｂ）に示されるように、エッチングストッパ層１３０５で停止させる。ドライエッチングでエッチングされるｐ型ＡｌＧａＩｎＰ第2クラッド層１３０６の厚さは、約１．５μｍである。このような厚い層を、第２の実施形態で説明したように、まず、スパッタ成分の強い第１のドライエッチングで１．３μｍ程度エッチングし、その後、化学反応成分の強い第２のドライエッチングで残りの０．２μｍ程度のｐ型ＡｌＧａＩｎＰをエッチングする。こうすれば、エッチングストッパ層１３０５より下の層に、エッチングによるダメージを及ぼすことはない。

【０１１１】また、第３の実施形態で説明したように、スパッタ成分の強いドライエッチングで、１．３μｍ程度の厚さの第２クラッド層１３０６をエッチングし、残りの０．２μｍ程度の第２クラッド層１３０６を、第２のエッチングとして、ウエットエッチングでエッチングしてもよい。

【０１１２】リッジ１３１３を形成したあと、図１３（ｃ）に示されるように、SiO_2マスク１３０７をそのまま用いて、ｎ型埋め込み層である、ｎ型ＧａＡｓ電流ブロック層１３０９を選択的に成長させる。

【０１１３】次に、SiO_2マスク１３０７を除去し、図１３（ｄ）に示されるように、ｐ型ＧａＡｓコンタクト層１３１０を成長させる。最後に、ｎ型ＧａＡｓ基板１３０１の裏面にｎ側電極１３１１、コンタクト層１３１０上にｐ側電極１３１２を形成して、レーザ構造が完成する。

【０１１４】本実施形態の半導体レーザ素子の製造方法において、リッジ１３１３の形成に、ハロゲンガスと窒素ガスとの流量比を約１．４≦塩素流量／窒素流量≦約４．０の範囲に設定することによって、リッジ１３１３の底面とリッジ１３１３の側面となす角度θは約６０度～９０度となるとともに、オフ基板を用いるにもかかわらず、対称性のよいリッジ形状を持つ半導体レーザ素子を製造することができる。このため、活性層へのキャリアの閉じ込め、光の閉じ込めが不均一にならず、横モードが安定な信頼性の高い半導体レーザ素子が得られる。さらに、本実施形態によると、Ａｌを含む化合物半導体のエッチングにもかかわらず、エッチングレートは低下しない。なお、以上の説明では、ｐ型ＡｌＧａＩｎＰ第２クラッド層をドライエッチングする工程において、第１のドライエッチングでＡｌＧａＩｎＰクラッド層を１．３μｍ程度エッチングした段階で条件を替え、第２のドライエッチングを行っている。ここで、１．３μｍ程度の厚さのＡｌＧａＩｎＰクラッド層がエッチングされたことを容易に検出（モニタ）するために、ＡｌＧａＩｎＰクラッド層のこの厚さの部分に、図１５（ａ）に示すように、ＡｌＧａＩｎＰ第２クラッド層１５０６と組成の異なるＧａＩｎＰ層１５００（厚さ：１０ｎｍ程度）を予め挿入していてもよい。

【０１１５】ＧａＩｎＰ層１５００を設けることによって、たとえばプラズマからの発光分析をしながらＡｌＧａＩｎＰ第２クラッド層をエッチングし、エッチングがＧａＩｎＰ層１５００までに進行した時点で、ＧａＩｎＰ層１５００はＡｌを含んでいないので、発光分析の値が変化する。この変化によって、第２クラッド層が１．３μｍ程度エッチングされたことを正確に検出できる。そして、エッチング条件を替えて、図１５（ｂ）に示されるように、第２のドライエッチングを行い、残りの約０．２μｍ厚さの第２クラッド層のをエッチングすればよい。こうすることによって、さらに、エッチング時のダメージが少なく、制御性よく、均一な特性を有する半導体レーザ素子を製造できる。

【０１１６】本実施形態によると、エッチングする試料にＡｌが含まれている場合、反応室内の残留水分によりAl_2O_3が形成されても、塩素ラジカル生成量が減少させることなく、塩素イオン生成量を増加することによって、スパッタリングでAl_2O_3の脱離を促進することができる。また、塩素ラジカルとＡｌとを反応させ、Ａｌは、塩化アルミニウムとなって脱離する。このため、試料がエッチングされなくなるか、エッチングレートが低下する問題は回避できる。

【０１１７】

【発明の効果】本発明によれば、次のような効果が得られる。

【０１１８】塩素流量/窒素流量を約１または１以上、内圧を約１mTorrまたは１mTorr以上に保持することにより、平滑なエッチング面を有するIII-V族、およびII-VI族化合物半導体のドライエッチングを行うことができる。

【０１１９】また、ラジカル源とイオン源を備え

たドライエッチング装置を用い、塩素イオン密度と塩素ラジカル密度および窒素イオン密度の量を独立に制御して、ドライエッチングを行うことにより、平滑なエッチング面を有するIII-V族、およびII-VI族化合物半導体のドライエッチングを行うことができる。

【図面の簡単な説明】

【図１】ＥＣＲ－ＲＩＢＥ装置の模式図

【図２】（ａ）および（ｂ）は、本発明の一実施形態におけるInPのドライエッチング後の断面図

【図３】本発明の一実施形態におけるInPのドライエッチング後の断面図

【図４】本発明の一実施形態におけるInPのドライエッチング後の断面図

【図５】本発明の一実施形態におけるInPのドライエッチング後の断面図

【図６】本発明の一実施形態におけるInPのドライエッチング後の断面図

【図７】基板を回転させながら均一にウエットエッチングするためのスピンエッチング装置の構成断面図

【図８】本発明の一実施形態におけるInPのドライエッチング後の断面図

【図９】ラジカルビーム源、イオンビーム源及びＥＣＲ源を備えたドライエッチング装置の構成断面図

【図１０】（ａ）～（ｃ）は、本発明の一実施形態おけるスポット径変換レーザの断面図

【図１１】（ａ）～（ｇ）は、図１０のスポット径変換レーザの製造工程断面図

【図１２】（ａ）～（ｃ）は、本発明の一実施形態における異なる条件の2段階ドライエッチングの模式図

【図１３】（ａ）～（ｄ）は、本発明の一実施形態における半導体レーザの製造工程断面図

【図１４】（ａ）および（ｂ）は、リッジの対称性を比較する半導体レーザの構成断面図

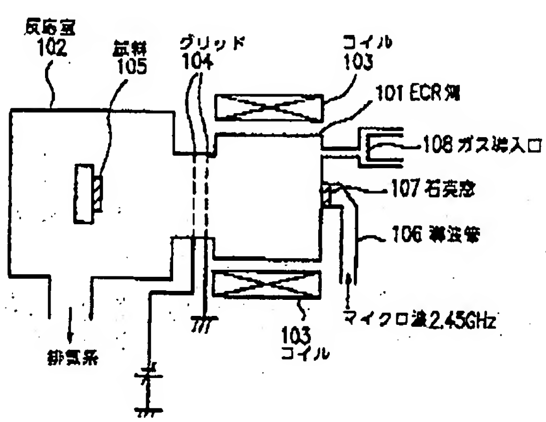
【図１５】（ａ）および（ｂ）は、クラッド層中にエッチング量のモニタ層を備えた半導体レーザの構成断面図

【図１６】プラズマ発光の分光結果を示す図

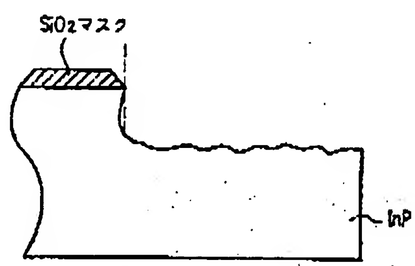
【符号の説明】

１０１　ECR源
１０２　反応室
１０３　コイル
１０４　グリッド
１０５　試料
７０２　試料保持台
７０３　ノズル
７０４　エッチャントタンク
７０５　反応室
９０２　ラジカルビーム源
９０３　イオンビーム源
９０４　ECR源
９０３１　引き出し電極
１００１　n-InP基板
１００２　n-InP
１００３　n-InGaAsPクラッド層
１００４　活性層
１００５　p-InGaAsPクラッド層
１００６　半絶縁性InP
１００７　p-InPキャップ層
１００８　n側電極
１００９　p側電極
１０１０　レーザ
１０１１　スポットサイズ変換部
１２０１　n-InP基板
１２０２　ＳｉＯ$_2$マスク
１２０３　加工誘起損傷層

【図１】



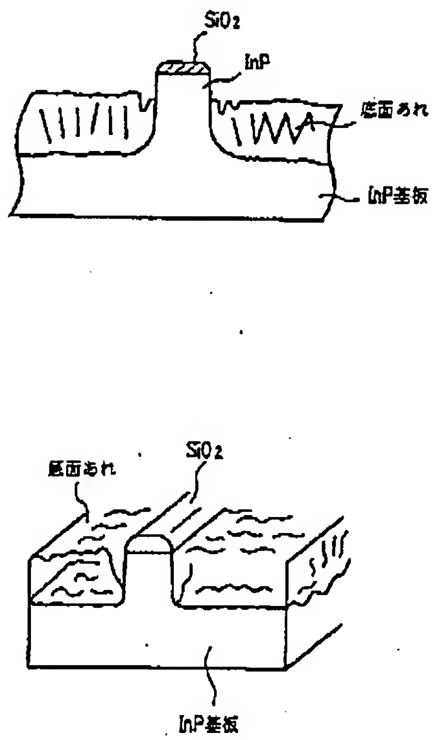
【図３】



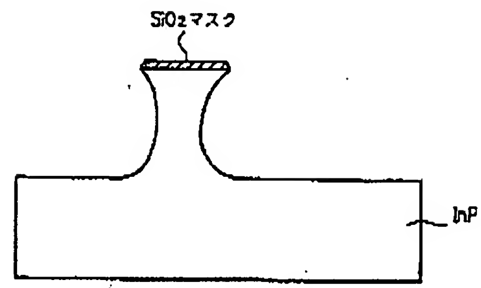
【図2】

(a)

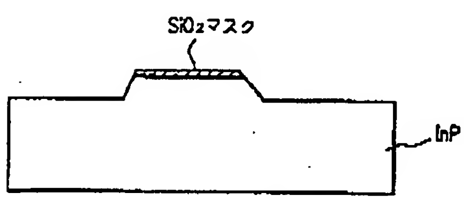
(b)



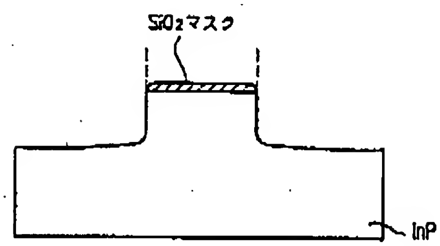
【図4】



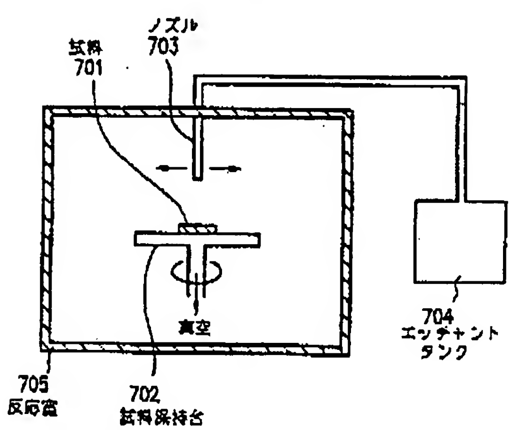
【図5】



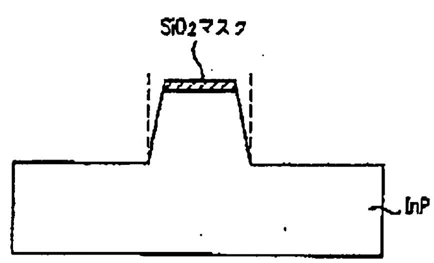
【図6】



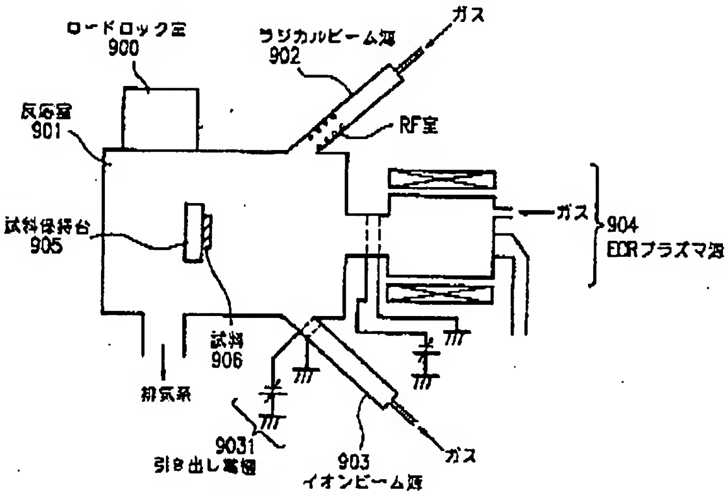
【図7】



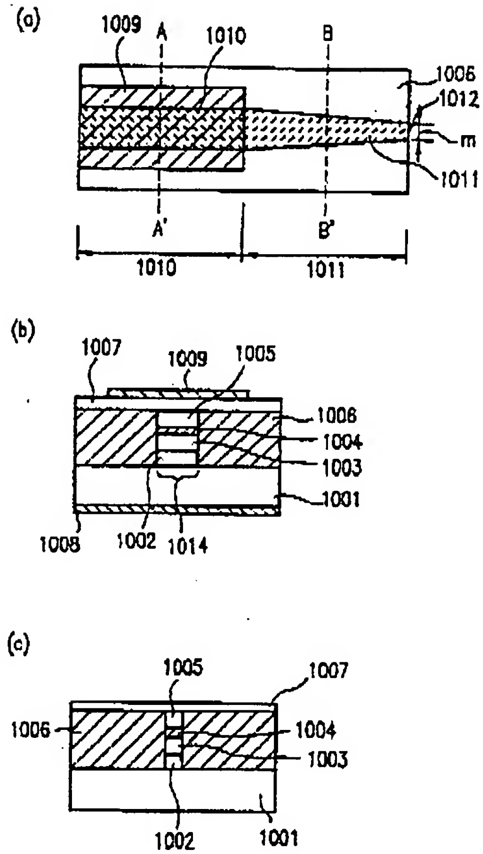
【図8】



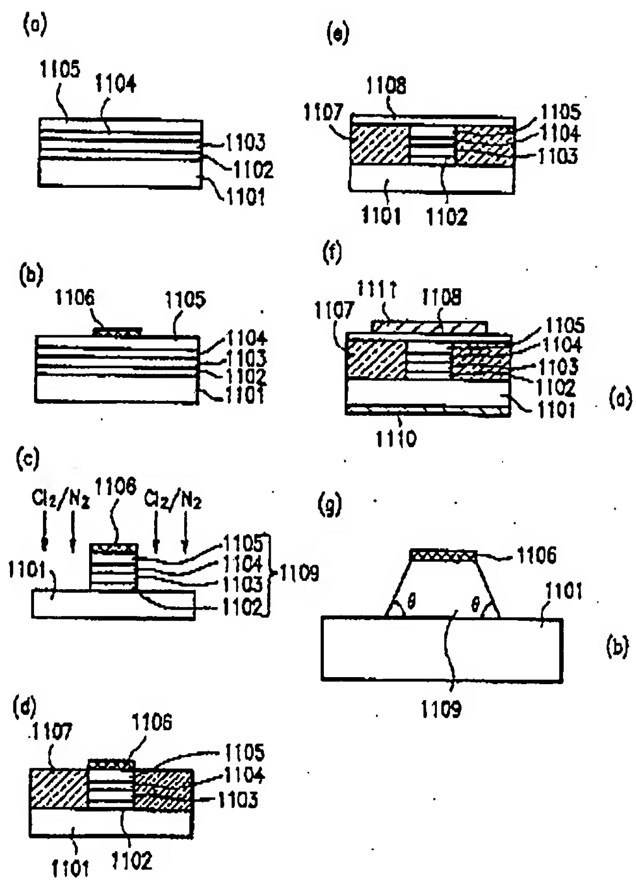
【図９】



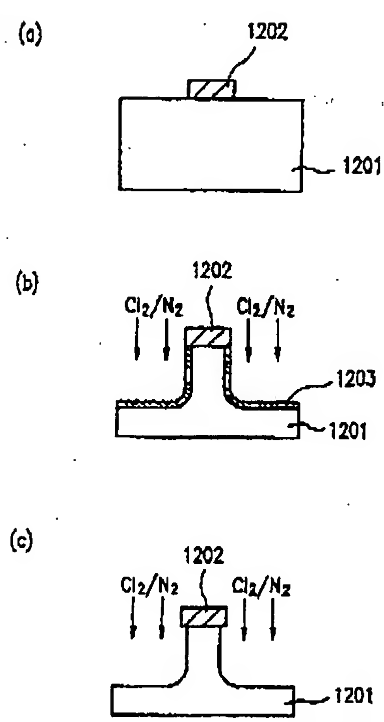
【図１０】



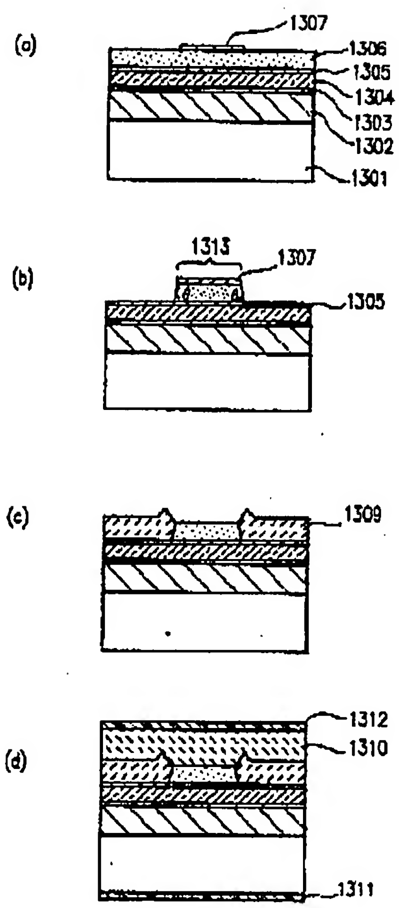
【図１１】



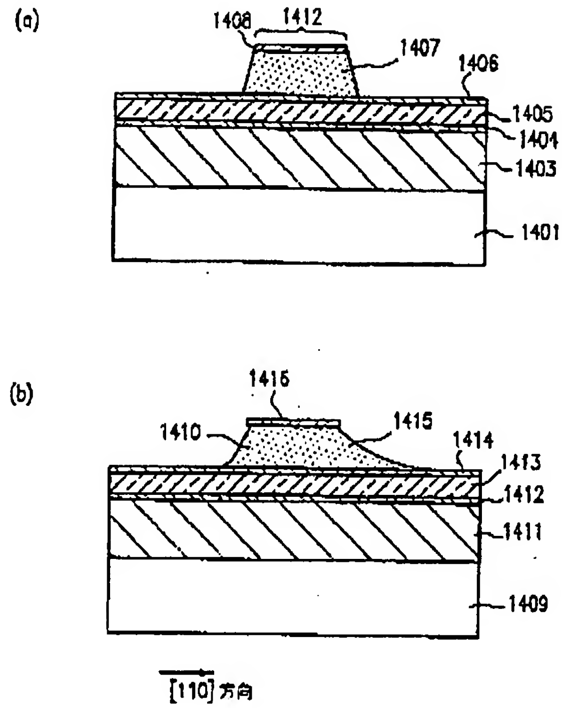
【図１２】



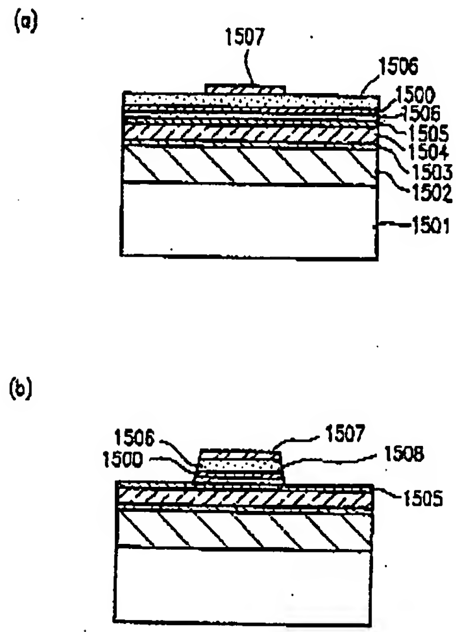
【図１３】



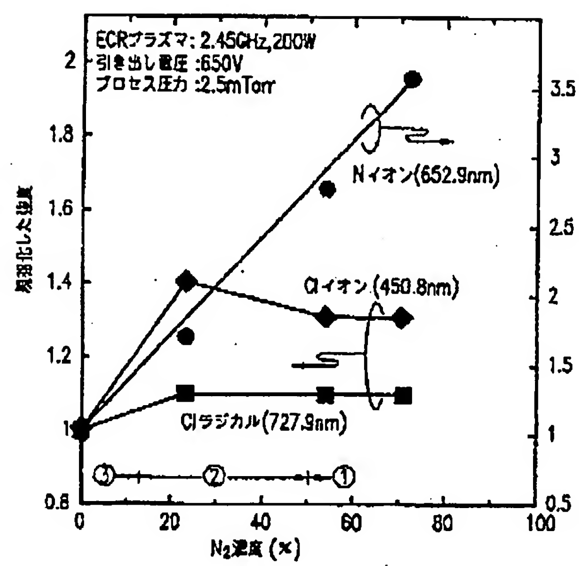
【図１４】



【図１５】



【図１６】



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